

Title Page

**Sound Levels In and Near the YUKON Military
Operations Areas, Alaska, 1999-2003**

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DATE: July 7, 2004 DRAFT

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Reference/Resource Page
(To be inserted in Final Report)

Executive Summary

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 Alaska, 1999-2003**

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Between 1999 and 2003, during the months of May, June, and July, sound levels were measured in east-central Alaska, in and near the YUKON Military Operations Areas (MOA). These data were collected to determine natural ambient sound conditions, to assess the influence of military jet aircraft on these natural sound conditions, and to provide acoustic data for related MOA studies (Human-use; Peregrine Falcon; and Neo-tropical Migrant Birds).

Over 14,800 hours of acoustic data were collected at twenty locations using a system of the authors' design that captured standard acoustic decibel data as well as digital recordings which allowed researchers to positively identify sources of acoustic events. Natural ambient sound levels (L_{90}) were lowest in Other Low Shrub habitat and highest in Open Needleleaf habitat. Means (and ranges) of natural ambient sound levels in the six most common habitats were:

Open Needleleaf	32.9 dBA (30.5-36.3 dBA)
Other Low Shrub	20.0 dBA (18.6-21.7 dBA)
Woodland Needleleaf	28.4 dBA (24.6-33.1 dBA)
Open Mixed Needleleaf/Deciduous	22.8 dBA (20.0-25.7 dBA)
Closed Mixed Needleleaf/Deciduous	21.0 dBA (19.2-23.2 dBA)
Tall Shrub	24.4 dBA (22.8-25.7 dBA)

Sound levels varied greatest among habitats and least among years (same hour and same habitat). Variability among hours of the day was less than those observed at lower latitudes, likely due to the 24-hour daylight conditions in interior Alaska in June and July. Sound levels during periods of routine training were lower than during periods of Cope Thunder exercises at most (but not all) measurement locations.

In the YUKON MOAs, 1083 events >65 dBA were recorded; 50 percent of these were due to natural sources (wind, thunder, rain, birds) and 41 percent were due to jet aircraft. The loudest sound recorded was 115.9 dBA from a jet aircraft (along the South Fork of Birch Creek in YUKON 2 MOA), while the loudest sound recorded in the restricted flight zone (Yukon and Charley rivers, 2,000 feet AGL/2-miles horizontal distance), also in the YUKON 2 MOA, was 109.4 dBA from a jet aircraft. Sound levels due to jet aircraft >85 dBA were recorded 19 times within the restricted flight areas. Overall, sounds from jet aircraft appear to occur less than 10 percent of the time in remote areas of the YUKON 1-4 MOAs (>30 miles from Eielson Air Force Base).

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Introduction

In the late 1980s and early 1990s, the Air Force initiated several actions that lead to a dramatic increase in training activity in Alaska. These actions included assigning squadrons of F-15s and F-16s to Elmendorf and Eielson Air Force Bases, respectively, increasing the number of Military Training Routes (MTR), initiating Major Flying Exercises (these include up to 75 aircraft), constructing the Yukon Debriefing System (to review training flights), and increasing the size of Military Operations Areas (MOA). Each of these actions included a separate Environmental Assessment, and all but the MOA increase were concluded with a Finding of No Significant Impact (FONSI). An Environmental Impact Statement (EIS) was prepared for the proposed MOA increase, and a Record of Decision (ROD) was signed in 1997 (Eleventh Air Force 1997). The Final EIS and the ROD included a number of mitigation measures designed to minimize negative impacts from the increases in training activity on both wildlife resources and human users. The ROD also established committees made up of Air Force and resource agency representatives to monitor the effectiveness of the mitigation measures. The committees recognized several high priority issues to study; one of these was collection of acoustic data for major habitats (vegetation types) and selected areas in and near the YUKON MOAs. This paper reports on sound levels in and near the YUKON MOAs between 1999 and 2003.

Currently, approximately 16,000 low-level flights (below 5,000 feet Above Ground Level) annually are authorized in Alaska MOAs for routine training operations. An equal

number above 5,000 feet AGL are also authorized annually. In addition to routine training operations, large force training exercises, referred to as Major Flying Exercises (MFE), occur as often as six times per year and add up to 5,000 additional low-level flights per year. Thus, approximately 21,000 low-level flights are authorized annually in Alaska.

Increases in military aircraft activity result in higher sound levels. Low-level aircraft in particular have the potential to adversely impact wildlife and human users of lands under the MOAs. Sound levels over 125 decibels (dB) can be expected from routine low-level training operations (Eleventh Air Force 1992). Observable effects in wildlife generally begin to appear at 85 to 90 dB, and startle or panic responses by most wildlife species occur at sound levels greater than 95 dB (Eleventh Air Force 1992). Wildlife species that can be impacted include threatened and endangered species, species of special concern, and game species important to subsistence and sport hunters. Human users that could be impacted include local residents, recreationists, subsistence users, and sport hunters and fisherman. Discernible effects on human users can occur when intrusive sound levels exceed natural ambient sound levels (Eleventh Air Force 1992). In order to assess potential impacts of military aircraft sound on wildlife and human users, knowledge of natural ambient sound levels and sound levels of military aircraft was needed.

Goals and Objectives

The purpose of this study was to measure sound levels in and near the YUKON MOAs to establish natural ambient sound levels in the major habitats of the MOAs, to measure sound levels during periods of routine military training and during periods of major flying exercises, primarily Cope Thunder exercises. Another purpose of the study was to identify sources and sound levels of sounds that were significantly higher than natural ambient sound levels.

Study Area

The study area was those lands in and near the YUKON MOAs in east-central Alaska (Figure 1). The area is bordered on the north and west by the Steese Highway and Circle, Alaska, on the east by the Alaska-Yukon Territory border, on the south and west by the Tanana River. The central part of this area is generally referred to as the Yukon-Tanana Uplands, characterized by rounded mountains, generally 1200–1500 m (3940–4920 ft) elevation (Wahrhaftig 1965). The two largest rivers in east-central Alaska, the Yukon and Tanana Rivers, flow generally from southeast to northwest. The vegetation in the river bottoms is generally a mosaic of wet meadows and shrub thickets, primarily dominated by various willow (*Salix* spp.), black spruce and white spruce (*Picea mariana* and *P. glauca*), and aspen (*Populus tremuloides*) woodlands and forests. Along the Yukon and Tanana rivers, and their major tributaries, cottonwood (*P. spp.*), balsam poplar (*P. balsamifera*), and white spruce forests, medium and tall shrub thickets

(primarily dominated by various *Salix* spp.), and sparsely vegetated gravel bars dominate. Gallant et al. (1995) provides a good description of the area, specifically the Interior Forested Lowlands and Uplands Ecoregion. Measurements were made outside the study along the Denali Highway (in the FOX MOA) and west of Fairbanks in the Bonanza Creek Experimental Forest.

The Bureau of Land Management (BLM), U. S. Air Force, and Ducks Unlimited developed an Earth Cover Classification System for areas in and near the YUKON MOAs (BLM 2002). This classification scheme was based on the Alaska Vegetation Classification by Viereck et al. (1992), with some adaptations. The primary earth cover classifications identified in this study, for the areas sampled in and near the YUKON MOAs, are listed in Table 1, in order of occurrence.

Nine habitats made up over 79 percent of total areas. Actual distribution of habitats within the YUKON MOAs may be somewhat different than these values; however, this distribution is likely representative of the YUKON MOAs. A brief description of the nine primary earth cover classifications as described by BLM (2002), the classification number of each, and the relative percentage of each in the sample area are provided in Table 1.

Figure 1. YUKON 1-4 Military Operations Areas, Alaska, and locations of acoustic data collection, 1999-2003.

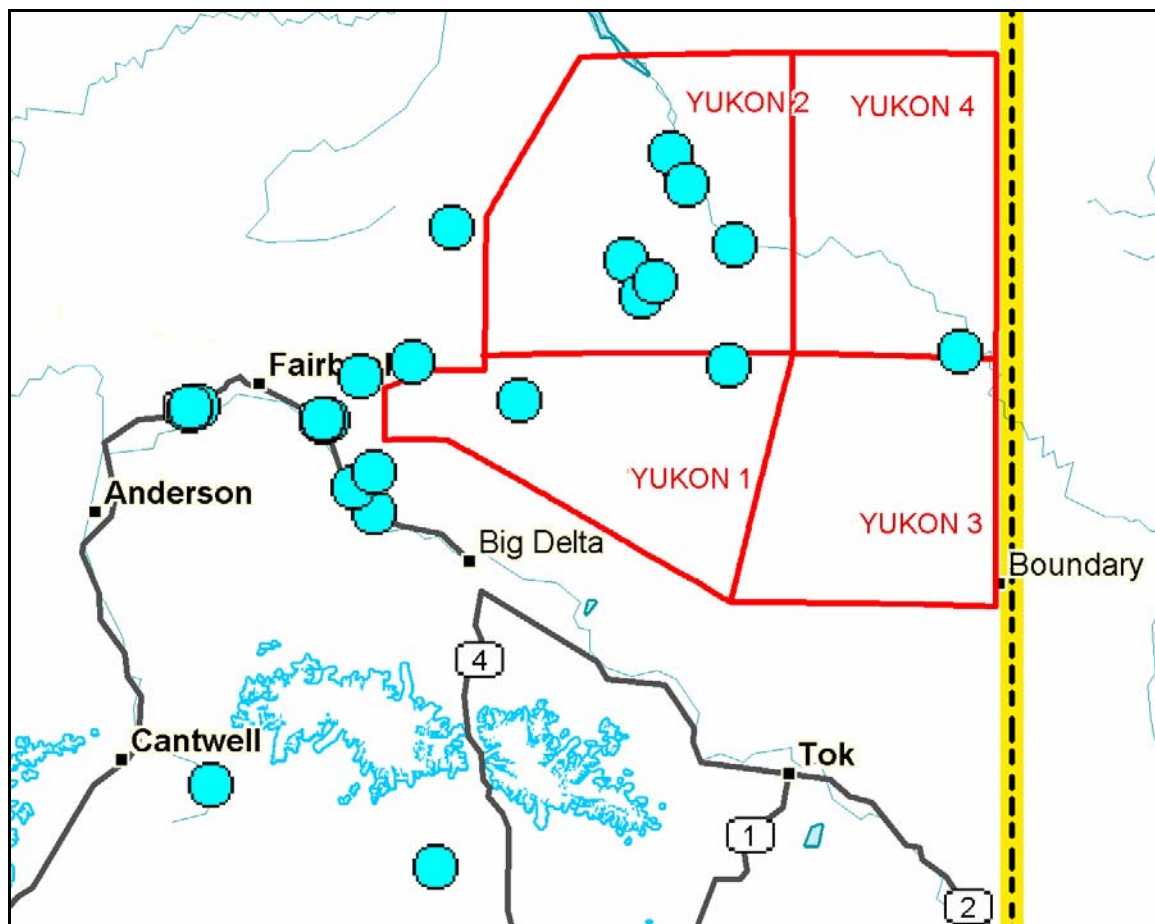


Table 1. Alaska Earth Cover Classification, Number, and Estimated Percent in and near YUKON MOAs (BLM 2002).

Earth Cover Classification	Class. Number	Percent of Total	Earth Cover Classification Description
Open Needleleaf	1.2	34.14	From 25-59% of the cover was trees, and $\geq 75\%$ of the trees were needleleaf with a height >1 meter.
Other Low Shrub	2.24	15.54	Shrubs made up 25-100% of the cover and either 25% of the site consisted of shrubs .25-1.3 meters in height OR shrubs .25-1.3 meters were the most common shrubs.
Woodland Needleleaf	1.3	11.02	From 10-24% of the cover was trees, and $\geq 75\%$ of the trees were needleleaf.
Open Mixed Needleleaf/Decid.	1.7	7.46	From 25-59% of the cover was trees, but neither needleleaf nor deciduous trees made up $\geq 75\%$ of the tree cover.
Closed Mixed Needleleaf/Decid.	1.6	3.6	At least 60% of the cover was trees, but neither needleleaf nor deciduous trees made up $\geq 75\%$ of the tree cover.
Tall Shrub	2.1	3.2	Shrubs made up 25-100% of the cover and either $\geq 25\%$ of the consisted of shrubs ≥ 1.3 meters in height OR shrubs ≥ 1.3 meters were the most common shrubs
Closed Deciduous	1.4	1.85	At least 60% of the cover was trees, and $\geq 75\%$ of the trees were deciduous.
Open Deciduous	1.5	1.85	From 25-59% of the cover was trees, and $\geq 75\%$ of the trees were deciduous.
Other Low Shrub/ Tussock Tundra	2.22	0.29	Shrubs made up 25-100% of the cover, $\geq 35\%$ of the cover was made up of tussock forming cotton grass (<i>Eriophorum vaginatum</i>), and either $\geq 25\%$ of the site consisted of shrubs .25-1.3 meters in height OR shrubs .25-1.3 meters in height were the most common shrubs.

Methods

Acoustic data were collected at 20 different locations between 1999 and 2003 (Table 2, Figure 1); data were collected at five locations for two or more years, resulting in 28 different measurements. Acoustic measurement duration targets varied, depending on site accessibility, interrelation with other studies, and in some cases, equipment performance. For the primary sites, those within the MOAs and at Eielson Air Force Base and Bonanza Creek Experimental Forest, our target was >500 hours, or >30 days. For other sites outside the MOAs, our target was >170 hours, or >7 days.

Acoustic data were collected in the primary habitats in and near the YUKON MOAs, and at specific locations where acoustic data were needed for related studies (human-use; peregrine falcon; neo-tropical migrant birds). Ten of the measurement locations were in the YUKON MOAs, and ten were outside the YUKON MOAs. Of the ten measurement locations in the MOAs, four were in areas without flight restrictions (Birch Creek and Salcha River), and six were in areas with flight restrictions (Yukon and Charley rivers). Areas of high, moderate, and low military use were sampled, as were areas of high, moderate, and low human use.

Definitions of acoustic terms are provided in Appendix I. Explanations of the most commonly used metrics follow.

Sound Levels: Metrics

Metrics commonly used to describe acoustic conditions, including L_{eq} , Percent Exceedence (such as L_{10} , L_{50} , L_{90}), and L_{min} and L_{max} , were calculated for all measurement locations. Hourly L_{eq} data were calculated using logarithmic means. Summary L_{eq} metrics (for several hours) were calculated using logarithmic means. In some previous acoustical studies, summary L_{eq} metrics were calculated using arithmetic means or medians rather than the logarithmic mean. Therefore, all three calculations are presented here (log mean, arithmetic mean, and median) for comparison purposes. Summary metrics for L_{10} , L_{50} , and L_{90} values were calculated using the median. The median was used because acoustic data from rural or wildland settings are rarely distributed normally (Ambrose, unpublished data), and, as a result, the arithmetic mean is not a good measure of central tendencies.

The L_{eq} (Energy Equivalent Sound Level) is the level of a constant sound over a specific time period that has the same sound energy as the actual (unsteady) sound over the same period. In rural or wildland settings, L_{eq} is useful for quantifying intruding sounds relative to ambient baseline sound levels because its magnitude depends heavily on the loudest periods of a time-varying sound. L_{eq} of an intruding source by itself, however, is inadequate for fully characterizing the intrusiveness of the source; metrics such as L_{max} , duration, and other should be used. L_{eq} is not a good metric for describing or estimating “normal” natural ambient acoustic conditions in a rural or wildland setting because one or a few loud sound events can greatly influence this metric.

Table 2. Acoustic Measurements Locations, Earth Cover Classification, and Human and Military Use, in and near YUKON MOAs, Alaska, 1999-2003.

Location	Latitude	Long.	AK Earth Cover	AK No.	Human Use	Military Use
Birch Creek 2041	65.3051	144.4315	Open Needleleaf	1.2	Low	High
Birch Creek 2050	65.209	144.1147	Open Needleleaf	1.2	Low	High
Birch Creek 2053	65.2231	144.1692	Open Needleleaf	1.2	Low	High
Birch Lake	64.3058	146.6622	Urban/Roads	7	High	Moderate
Bonanza Creek Exp. Forest	64.7214	148.3284	Closed Mixed Needleleaf/Decid.	1.6	Low	Low
Brushkana State Park	63.2901	148.0643	Open Needleleaf	1.2	Moderate	Low
Charley River	64.8187	143.4415	Woodland Needleleaf	1.3	Low	High
Chena Rec., Granite Tors	64.9036	146.3629	Open Needleleaf	1.2	High	High
Chena Rec., Twin Bears	64.8965	146.6733	Open Needleleaf	1.2	High	High
Eielson Air Force Base	64.6974	147.1253	Closed Mixed Needleleaf/Decid.	1.6	High	High
Harding Lake State Park	64.4373	146.8793	Urban/Roads	7	High	Moderate
Pinnel Mountain Trail	65.4164	145.9746	Other Low Shrub	2.24	Low	Moderate
Salcha R., N. Fork (Bonanza Ck)	64.7639	145.3284	Other Low Shrub/Tussock Tundra	2.22	Low	High
Salcha River (near bridge)	64.4674	146.9133	Closed Deciduous	1.4	High	High
Tangle Lakes State Park	63.0507	146.003	Tall Shrub	2.1	Moderate	Low
Yukon River 57.5	64.9795	141.3715	Open Mixed Needleleaf/Decid.	1.7	Low	Low
Yukon River 205.5	65.4327	143.632	Tall Shrub (willow)	2.1	Low	Moderate
Yukon River 235.0	65.6035	143.9951	Open Deciduous	1.5	Low	Moderate
Yukon River 244.0	65.6726	144.0622	Tall Shrub (willow)	2.1	Low	Moderate
Yukon River 249.0	65.7132	144.0641	Tall Shrub (willow)	2.1	Low	Moderate

The Percent Exceedence metric (L_x) is the sound levels (L), in decibels, exceeded x percent of the time. The L_{50} value represents the sound level exceed 50 percent of the time for a given period. L_{50} is the same as the median. The L_{90} value represents the sound level exceeded 90 percent of the time for a given time period. For acoustic conditions with few sounds that greatly exceed normal ambient conditions, and for areas with little normal variability, the L_{50} and L_{90} values generally differ by <5 dB. Percent Exceedence metrics are often used to describe baseline conditions for a given environment for assessing impacts due to proposed actions. The L_{50} metric (the median) is used to describe natural ambient sound levels if no non-natural sounds are present. During this study at most measurement locations on most days, there were non-natural sounds. Generally, it is prohibitively expensive or not feasible to measure actual natural ambient sound levels and separate them from non-natural sound sources (one has to record and physically remove non-natural sounds from recordings and re-calculate acoustic metrics, a very labor intensive process). In these cases, the L_{90} metric is generally used to describe natural ambient sound levels (B&K 2001; Berglund and Lindvall 1995, Dunholter et al. 1989; NPS 1995; NPS 2002; several state laws, including Massachusetts, Connecticut, Illinois; and many countries). For this study, the L_{90} metric was used to describe natural ambient sound levels.

At locations with very infrequent non-natural sounds, the L_{90} values reported herein likely under-estimates natural ambient sound levels. Conversely, because all locations had some degree of non-natural sounds, the L_{50} likely over-estimates natural ambient sound levels. For this reason, both the L_{50} and the L_{90} are reported. At some locations,

such as near Eielson Air Force Base, non-natural sounds were audible 100% of the time, hence it was not possible to determine or estimate natural ambient sound levels.

Sound Levels: Routine Training and Cope Thunder Exercises

Sound levels (dBA) during primary flight hours (1000-1800) for routine training periods were compared to sound levels for major flying exercise periods. Because other non-natural sounds greatly influenced sound levels in urban locations (such as Harding Lake and Birch Lake), only remote sites in the YUKON MOAs were used for this analysis.

Most of the training flights in May, June, and July in the YUKON MOAs occur between 1000 and 1800. Although military aircraft frequently take off and land before and/or after those times, the majority of flights in the YUKON MOAs occur during these times. Therefore, for the purposes of calculating sound levels specifically addressing military aircraft, only the acoustic data between 1000 and 1800 were used.

Identification of Sources of Sounds >65 dBA

In order to identify sources of relatively loud sounds in the YUKON MOAs, acoustic monitors were programmed to make digital recordings (.wav files) of all sound events that exceeded a user-defined threshold (dBA) and duration (seconds). These allowed

investigators to play back the recordings at a later date and identify the sources of the sounds (see below for a discussion of the monitors and software). Threshold and duration levels varied depending on the natural ambient sound conditions at each location, but at all locations, all events over 65 dBA and longer than 10 seconds were recorded. In order to insure that very loud but very short events, such as sonic booms, were captured, monitors had a second trigger for these types of events. This “short” trigger was set to 75 dBA or 85 dBA and 0.125 seconds. All events that exceeded these thresholds were recorded, and investigators identified the source of all sounds that exceeded these thresholds. Because sonic booms are of very short duration (<1 second), response time was set to “fast” in sound level meters. This “fast” setting insured that loud but short events would trigger the digital audio recording capture process.

Sound Levels: Differences by Habitat, Hour, and Year

Several factors have the potential to influence sound levels in wildland areas, including habitat type and associated animals, water, weather, the attenuation of sounds due to vegetation and terrain, and daily, seasonal, and annual variation. Generally, it is assumed that similar habitats and terrain support similar animals, and, assuming other factors are comparable (such as flowing water and weather), sound levels are assumed to be similar. What is less well understood is the variability of sound levels due to hourly, seasonal, and annual variation. For locations where a reasonable amount of data (>400 hours) were collected for two or more years, hourly and annual differences will be compared.

Since all measurements were made during one season (summer), seasonal differences cannot be assessed.

Equipment

New acoustic monitors were developed for this study that allowed researchers to collect traditional decibel data as well as digital recordings of high-level sound events, including periods before and after the event. Monitors consisted of a notebook computer with built-in sound capability, a Type 1 sound level meter, microphone (with windscreen), and preamplifier (American National Standards Institute 1984), 12-volt battery system, photovoltaic charging system, and weatherproof container. The 12-volt battery power supply and photovoltaic charging system enabled the sound monitors to operate continuously. Acoustic monitors collected 1-second Leq dBA sound levels continuously during all hours of operation. In addition to collecting sound level data, all loud (user-defined threshold) sound events were monitored and saved as .wav files (digital recordings). Any sound event exceeding a user-defined threshold (dBA) and duration (seconds) were saved as a .wav file on the hard drive of the notebook computer. This allowed investigators to play back the recordings and determine the source of the sound (thunder, bird, animal, aircraft, boat, gunfire, etc.). Acoustic monitors used SoundMonitor software (© Far North Aquatics, Fairbanks, AK) to control the sound level meter and digital recording process. Monitors were checked and data files retrieved monthly. We used SoundStat and HourlyCalculator (both © Far North Aquatics, Fairbanks, AK) to analyze acoustic data.

Larson-Davis Model 812 sound level meters, with Larson-Davis Model 2560 microphones and Larson-Davis Model 828 preamplifiers, were used in this study. B&K Model 4231 calibrators were used for field calibration check. All equipment was calibrated annually by Larson-Davis or another certified facility.

Specific methodologies (standards or protocols) for equipment type, microphone type, microphone placement and height, and other factors are presented in Appendix II. These standards were based in part on American National Standard ANSI S12.9-1992, Part 2 (ANSI 1992), Methodology for the Measurement Of and Analysis of Aircraft Sound Levels within National Parks (Dunholter et al. 1989), and Draft Guidelines for the Measurement and Assessment of Low-level Ambient Noise (Fleming et al. 1998).

A field data sheet was completed for each measurement location and for each visit. Basic site information, time arrive/time leave, latitude and longitude, habitat/vegetation types (three primary vegetation types and percentage of each), equipment type and serial numbers, and software settings were completed for each site. During every visit, time offsets were noted (GPS time versus computer time); computer clocks were set to GPS time, data were downloaded to a portable hard drive, and calibration levels were checked (differences from 94.0 dB were noted and recalibrated if >0.5 dBA). During every visit to the monitors, calibration data (94 dB @ 1,000 Hz) were saved to the hard drive. Additionally, the minimum levels the meters were capable of measuring were measured using a dummy microphone and recorded on data sheets and saved to the hard drive.

The original schedule for this project called for data to be collected in 1999 and 2000; however, the study was extended due to cancellation of major flying exercises in 1999 (due to military conflict in Europe) and in 2000 (due to runway reconstruction at Eielson AFB). In 2001, the June 11-27 Cope Thunder exercise was also cancelled. With so many changes in training schedules, it appeared unlikely that a “normal” training schedule would be possible; thus, the project started in earnest in 2001. Most data were collected in 2001 and 2002, although limited data were collected in 1999, 2000, and 2003.

Photographs of equipment at several measurement locations are in Appendix III.

Results

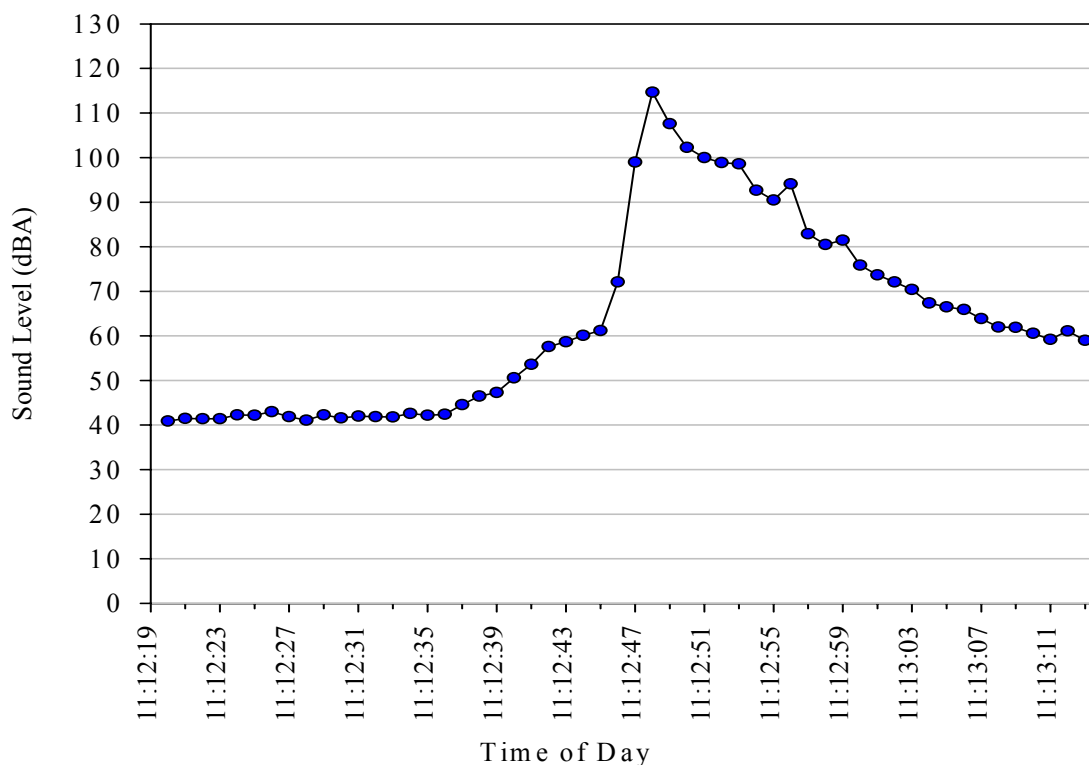
Sound Levels

A total of 14,809 hours of acoustic data were collected during May, June, and July, 1999-2003 (Table 3). Duration of acoustic measurements per location ranged from 48 hours to 1512 hours, with a mean of 529 hours. Summary metrics for all locations and all years, for periods with and without Cope Thunder exercises, are presented in Appendix IV.

For all measurement data reported in this report, very low dBA values <20 dBA were likely influenced by the minimum measurement capabilities of the sound level meters, hence actual sound levels could be less than reported.

Non-natural sounds, primarily jet aircraft, were detected at all measurement locations in the YUKON MOAs. The maximum sound level measured was 115.9 dBA (Figure 2; jet aircraft in the YUKON 1 MOA), and the lowest sound level was 17.7 dBA.

Figure 2. Sound level of jet aircraft, Birch Creek 2041, Alaska, June 17, 2002.



The highest sound level recorded in the restricted flight zone (2,000 feet Above Ground Level or 2 miles horizontal distance from Yukon and Charley rivers) was 109.4 dBA at YUKO 249.0, a peregrine falcon nest site about 10 miles upriver from Circle, AK. Nineteen events >85 dBA were recorded at four of the six measurement locations in the restricted flight zones.

Hourly L_{90} dBA and L_{50} dBA for nine earth cover types (BLM 2002) are presented in Tables 4 and 5. For earth cover types where acoustic data were collected at more than one location or for more than one year, the means of the hourly L_{90} and L_{50} levels are presented. At locations where non-natural noise was continuous or nearly so, natural

ambient sound levels could not be determined and these locations were excluded from calculating natural ambient sound levels only. For the nine different earth cover types, the difference between the L_{90} and L_{50} metric for all hours averaged 3.1 dB (range 1.5-4.1). L_{90} values for all habitats ranged from 18.3 dBA to 36.3 dBA, and L_{50} values for all habitats ranged from 20.5 dBA to 41.1 dBA. The lowest mean sound levels were recorded in “Other Low Shrub” habitat (L_{90} =20.0 dBA for all hours and L_{50} =20.5 dBA for all hours), while the highest were in “Open Needleleaf” habitat (L_{90} =32.9 dBA for all hours and L_{50} =34.5 dBA for all hours).

Table 3. Number of hours of acoustic data collected, by location and by year, in and near the YUKON MOAs, Alaska, 1999-2003.

Location	Year	Hours
Birch Creek 2041	2002	288
Birch Creek 2050	2002	208
Birch Creek 2053	2001	576
Birch Creek 2053	2002	285
Birch Lake	2001	155
Bonanza Creek Experimental Forest	2000	109
Bonanza Creek Experimental Forest	2001	738
Bonanza Creek Experimental Forest	2002	1512
Brushkana State Park	2001	85
Charley River, middle section	2001	715
Chena River Rec., GraniteTors	2001	214
Chena River Rec., Twin Bears	2001	283
Eielson Air Force Base	2000	711
Eielson Air Force Base	2001	1471
Eielson Air Force Base	2002	1288
Harding Lake State Park	1999	48
Harding Lake State Park	2001	827
Pinnel Mountain Trail	2001	1027
Salcha River (Richardson Hwy. bridge)	2001	406
Salcha River, North Fork, Bonanza Creek	2001	724
Tangle Lakes State Park	2001	142
Yukon River 57.5	2002	165
Yukon River 235.0	2001	525
Yukon River 205.5	2002	584
Yukon River 244.0	1999	463
Yukon River 249.0	2001	405
Yukon River 249.0	2002	291
Yukon River 249.0	2003	564
Total Number of Hours:		14809

Table 4. L₉₀ dBA sound levels in major habitats in YUKON MOAs, Alaska, 1999-2003.

Earth Cover Type and Earth Cover Number	Open Needleleaf	Woodland Needleleaf	Closed Decid.	Open Decid.	Closed Mixed Ndl./Decid	Open Mixed Ndl./Decid	Tall Shrub	Low Shrub/ Tuss. Tundra	Other Low Shrub
	1.2	1.3	1.4	1.5	1.6	1.7	2.1	2.22	2.24
Hour:									
0:00	36.3	32.7	29.9	22.5	19.4	21.1	23.8	30.7	21.0
1:00	36.0	33.1	30.1	22.5	19.2	20.6	23.5	31.2	21.7
2:00	35.6	32.7	30.1	23.3	19.3	20.1	23.7	31.3	21.7
3:00	35.4	32.7	30.1	23.4	19.5	20.0	23.3	30.9	21.0
4:00	35.5	32.4	29.6	22.7	19.3	20.3	23.4	30.6	21.1
5:00	34.9	31.6	31.0	22.0	19.2	20.6	23.3	29.9	20.1
6:00	34.0	28.6	32.1	22.2	20.0	21.6	22.8	29.0	19.0
7:00	32.1	26.7	31.5	22.1	20.5	25.7	23.4	28.6	18.9
8:00	31.0	25.1	31.6	21.9	20.7	24.3	24.3	28.3	18.6
9:00	30.5	24.8	31.6	22.4	21.3	24.4	24.6	28.5	18.7
10:00	30.7	24.6	32.0	22.8	21.8	23.2	24.6	28.2	18.9
11:00	30.8	25.3	34.1	23.4	22.4	23.1	25.4	28.3	19.1
12:00	30.8	24.8	33.9	24.2	23.1	24.3	25.5	28.9	19.0
13:00	30.9	25.7	33.0	25.0	23.1	24.5	25.7	28.3	19.2
14:00	30.7	26.7	34.6	25.5	23.0	25.1	25.4	29.0	19.4
15:00	30.9	26.1	34.1	25.7	23.2	24.2	25.4	28.8	19.3
16:00	30.9	26.6	34.9	25.1	22.4	23.9	25.7	28.6	19.8
17:00	31.2	27.5	35.4	25.3	23.1	23.2	25.7	29.0	20.0
18:00	31.8	26.5	34.4	24.5	22.2	23.2	25.4	28.4	19.7
19:00	32.7	26.7	31.4	23.2	22.0	24.6	24.8	28.8	20.1
20:00	32.4	28.2	32.3	22.6	21.0	22.9	24.5	29.9	20.2
21:00	33.3	28.7	31.7	22.9	20.3	21.5	23.6	30.8	20.7
22:00	34.7	30.9	31.3	23.4	19.5	22.9	23.3	30.3	20.9
23:00	35.8	32.4	30.8	22.4	19.7	21.2	23.6	30.5	21.0

Table 5. L₅₀ dBA sound levels in major habitats in YUKON MOAs, Alaska, 1999-2003.

Earth Cover Type and Earth Cover Number	Open Needleleaf	Woodland Needleleaf	Closed Decid.	Open Decid.	Closed Mixed Ndl./Decid	Open Mixed Ndl./Decid	Tall Shrub	Low Shrub/ Tuss. Tundra	Other Low Shrub
	1.2	1.3	1.4	1.5	1.6	1.7	2.1	2.22	2.24
Hour:									
0:00	37.7	34.9	33.3	24.7	21.5	23.0	26.6	32.0	23.6
1:00	37.6	34.4	32.5	27.2	21.5	21.7	27.1	32.4	23.6
2:00	37.0	34.3	32.3	30.1	24.3	21.3	27.9	32.6	23.3
3:00	36.9	34.2	32.0	28.5	26.0	21.3	28.2	32.2	23.2
4:00	36.9	34.5	33.0	27.8	24.0	23.6	27.6	32.1	22.6
5:00	36.2	33.2	33.1	25.1	24.4	23.6	27.5	31.2	22.6
6:00	35.7	31.0	34.0	25.5	24.9	24.3	27.3	30.2	20.9
7:00	33.6	28.4	33.7	25.0	26.1	28.4	28.0	29.4	21.0
8:00	32.1	26.4	34.1	24.6	26.7	28.7	28.0	29.3	20.8
9:00	31.5	25.8	36.4	25.6	26.6	28.0	27.8	29.5	20.5
10:00	32.2	25.9	37.0	25.7	26.5	26.4	28.6	29.2	22.2
11:00	32.6	27.0	38.2	25.7	27.4	24.6	29.9	29.4	23.2
12:00	32.7	26.6	38.1	26.1	28.7	30.9	29.1	30.5	23.0
13:00	32.7	28.7	38.9	27.9	29.4	28.9	29.8	30.3	25.5
14:00	32.4	28.9	40.4	31.1	30.5	31.3	28.9	31.4	27.3
15:00	33.5	29.2	39.7	29.7	30.0	30.5	28.6	31.5	24.6
16:00	33.3	29.7	41.1	29.6	29.5	29.1	29.8	31.2	27.9
17:00	33.1	30.6	40.5	28.5	29.8	25.5	30.7	30.5	25.6
18:00	33.7	29.0	39.2	28.8	28.0	28.4	28.1	30.6	26.1
19:00	34.0	28.8	37.3	25.3	27.9	27.0	28.7	30.4	25.7
20:00	34.5	29.9	37.0	24.6	26.2	25.7	27.9	31.3	24.2
21:00	35.2	31.5	36.0	25.2	25.0	24.5	26.5	31.8	23.5
22:00	36.3	33.0	36.8	24.9	23.2	24.6	25.6	31.2	23.7
23:00	37.3	34.1	35.5	24.2	22.2	22.5	25.9	31.5	23.7

Sound Levels: Routine Training and Cope Thunder Exercises

Sound levels during periods of major flying exercises were generally higher than during periods of routine training (Log mean for all periods of Cope Thunder exercises was 69.3 dBA; Log mean for all periods of routine training was 64.2 dBA) (Table 6). Some locations in the YUKON MOAs were higher during periods of routine training; this may be due to the random nature of training exercises, or it may be the measurement location was very near a particularly good area or route frequently used for training maneuvers.

Table 6. Sound levels (L_{eq} dBA, log mean and median) at remote YUKON MOA locations during routine training and during Cope Thunder exercises, 2001-2002 (primary flight hours only, 1000-1800).

Year	Location	L_{eq}	L_{eq}
		w/o Cope T.	w/ Cope T.
2002	Birch 2041	39.5	62.6
2002	Birch 2050	49.8	41.8
2001	Birch 2053	52.7	49.4
2002	Birch 2053	45.5	42.9
2001	Charley River	55.8	45.1
2001	North Fork Salcha River, Bonanza Creek	50.3	51.3
2002	Yukon 205.5	38.2	41.9
2001	Yukon 235.0	45.6	52.0
2001	Yukon 249.0	42.9	52.4
2002	Yukon 249.0	37.4	57.6
2003	Yukon 249.0	43.3	42.3
	Log Mean	49.1	54.4
	Medium	45.5	49.4

Sound Levels >65 dBA, Sources and Maximum Levels

Sources of sounds and sound levels (2000-2003) are presented for two different types of measurement locations: those in remote areas of the YUKON MOAs and those in urban-like areas. In the YUKON MOAs, these sites were Birch2041, Birch2043, Birch2050, Charley River, Pinnel Mountain Trail, Salcha River North Fork, YUKO57.5, YUKO205.0, YUKO235.0, YUKO244.0, and YUKO249.0. The measurement locations in the urban-type area were Birch Lake, Brushkana, Harding Lake, near the Richardson Highway bridge over the Salcha River, Tangle Lakes, and Twin Bears. Source data from the Granite Tors location are not presented here due to nearly continuous road constructions sounds, and data from Bonanza Creek Experimental Forest were not presented here because it is primarily a rural location but not in a MOA. The Eielson Air Force Base data are not presented here because nearly all events were aircraft taking off or landing.

At the YUKON MOA locations, 1083 events ≥ 65 dBA and ≥ 10 seconds and/or ≥ 75 dBA (≥ 85 dBA in some cases) and ≥ 0.125 seconds were recorded (Table 7). The majority of these, 440 or 40.6% were Jet Aircraft. The second most common source was Wind (324 events; 29.9%), followed by Thunder (86 events; 7.9%), Rain (70 events; 6.5%), Bird (67 events; 6.2%), Propeller Aircraft (52 events; 4.8%), Helicopter (30 events; 2.8%); Animal (11 events; 1.0%); People (2 events; 0.2%); and Watercraft (1 event; 0.1%).

In the YUKON MOAs, the mean dBA of the jet aircraft events was 75.6 dBA (range 65.0-115.9 dBA). The mean dBA of wind events was 71.8 dBA (65.0-83.4 dBA). It is important to remember that these mean dBA values represent only those events ≥ 65 dBA; there were many more sounds by all of these sources that were < 65 dBA.

At urban-type measurement locations 622 events ≥ 65 dBA and ≥ 10 seconds and/or ≥ 85 dBA and ≥ 0.125 seconds were recorded (Table 8). The most common non-natural sounds were generators from recreational vehicles at campgrounds (referred to Non-natural, Other, 254 events; 40.8%, Jet Aircraft (190 events; 30.5%), Watercraft (80 events; 12.9%; mostly airboats near the Salcha River bridge), Vehicle (60 events; 9.6%), Propeller Aircraft (15 events; 2.4%), Rain (12 events; 1.9%), Helicopter (6 events; 1.0%), Wind (3 events; 0.5%), People (1 event; 0.2%), and Animal (1 event; 0.2%).

In the urban area locations, the mean dBA of Jet Aircraft events was 79.0 dBA (range 65.0-110.2 dBA). The mean dBA of Non-natural, Other events was 77.8 dBA (65.1-80.3 dBA). As with events discussed in the YUKON MOAs, it is important to remember that these mean dBA values represent only those events ≥ 65 dBA; there were many more sounds by all of these sources that were < 65 dBA, especially in the urban areas.

Table 7. Source of events ≥ 65 dBA and ≥ 10 seconds or ≥ 75 dBA (≥ 85 dBA at some locations) and ≥ 0.125 seconds at measurement locations in the YUKON MOAs, Alaska, 2000-2003.

Source:	Number of Events:	Percent:	Mean Event dBA	Comments
Aircraft, Jet	440	40.6%	75.6	
Aircraft, Prop	52	4.8%	71.5	
Aircraft, Helo	30	2.8%	76.5	
Watercraft	1	0.1%	65.6	
People	2	0.2%	84.4	People yelling at microphone.
Wind	324	29.9%	71.8	
Rain	70	6.5%	66.5	
Thunder	86	7.9%	74.1	
Bird	67	6.2%	79.8	Song bird vocalization very close to microphone.
Animal	11	1.0%	81.1	Bear chewing foam windscreen.

Table 8. Source of events ≥ 65 dBA and ≥ 10 seconds or ≥ 85 dBA and ≥ 0.125 seconds at urban-type measurement locations, Alaska, 2000-2003.

Source:	Number of Events:	Percent:	Mean Event dBA:	Comments:
Aircraft, Jet	190	30.5%	79.0	
Aircraft, Prop	15	2.4%	73.6	
Helicopter	6	1.0%	72.2	
Vehicle	60	9.6%	68.6	
Watercraft	80	12.9%	77.8	Several airboats near Salcha River bridge.
People	1	0.2%	65.7	
Non-natural, other	254	40.8%	72.2	Nearly all were generators at campgrounds.
Wind	3	0.5%	69.6	Wind with rain.
Rain	12	1.9%	67.3	
Animal	1	0.2%	65.3	

Sound Levels: Differences by Habitat, Hour, and Year

Variability within and between habitats, hours and years was assessed by ranking differences in sound levels (L_{90} dBA and L_{50} dBA) for habitat, hour, and year, from highest (rank score 1) to lowest (rank score 3). Of these three factors, habitat showed the most variability, whereas variability within hours for different days at the same site showed less variability, and differences between different years for the same hour and site showed the least variability (Tables 9-12).

Rank differences within habitat, hour and year were:

Rank	Factor
Habitat	1
Hour	2
Year	3

Differences among habitats

L_{90} : mean difference between habitats: 14.7 dBA (all hours); range 12.2-16.9 dBA

L_{50} : mean difference between habitats: 14.3 dBA (all hours); range 12.0-16.3 dBA

Differences among hours of the day for the same habitat

L_{90} : mean difference among hours (same habitat): 4.8 dBA; range=3.0-8.5 dBA

L_{50} : mean difference among hours (same habitat): 7.3; range 3.4-10.0 dBA

Differences among years for the same hour at the same habitat

For two locations (see Tables 13 and 14) where >400 hours of acoustic data were collected for two years, mean difference between same hours were:

YUKO 249.0: L₉₀: mean difference (same hour): 1.6 dBA; range=0.2-3.1 dBA
 L₅₀: mean difference (same hour): 1.6 dBA; range= 0.1-4.7 dBA

Bonanza Creek: L₉₀: mean difference (same hour): 1.9 dBA; range=0.0-3.2 dBA
 L₅₀: mean difference (same hour): 2.2 dBA; range 0.0-4.0 dBA.

Table 9. Differences in L_{90} (mean, minimum and maximum for all hours) for each earth cover type, May-July, 1999-2003, Alaska.

Earth Cover Num.	Mean	Min	Max	Diff.
1.2	32.9	30.5	36.3	5.8
1.3	28.4	24.6	33.1	8.5
1.4	32.1	29.6	35.4	5.8
1.5	23.4	21.9	25.7	3.9
1.6	21.0	19.2	23.2	4.1
1.7	22.8	20.0	25.7	5.7
2.1	24.4	22.8	25.7	3.0
2.2	29.4	28.2	31.3	3.1
2.2	20.0	18.6	21.7	3.1

Table 10. Differences in L_{90} (mean, minimum, and maximum for nine earth cover types) for each hour of day, May-July, 1999-2003, Alaska.

Hour:	Mean	Min	Max	Diff.
0	26.4	19.4	36.3	16.9
1	26.4	19.2	36.0	16.9
2	26.4	19.3	35.6	16.3
3	26.3	19.5	35.4	16.0
4	26.1	19.3	35.5	16.2
5	25.8	19.2	34.9	15.7
6	25.5	19.0	34.0	15.0
7	25.5	18.9	32.1	13.2
8	25.1	18.6	31.6	13.0
9	25.2	18.7	31.6	12.9
10	25.2	18.9	32.0	13.1
11	25.8	19.1	34.1	15.0
12	26.0	19.0	33.9	14.9
13	26.1	19.2	33.0	13.8
14	26.6	19.4	34.6	15.3
15	26.4	19.3	34.1	14.8
16	26.4	19.8	34.9	15.1
17	26.7	20.0	35.4	15.4
18	26.2	19.7	34.4	14.7
19	26.0	20.1	32.7	12.6
20	26.0	20.2	32.4	12.2
21	25.9	20.3	33.3	13.0
22	26.4	19.5	34.7	15.2
23	26.4	19.7	35.8	16.1

Table 11. Differences in L_{50} (mean, minimum and maximum for all hours) for each earth cover type, May-July, 1999-2003, Alaska.

Earth Cover Num.	Mean	Min	Max	Diff.
1.2	34.5	31.5	37.7	6.2
1.3	30.4	25.8	34.9	9.1
1.4	36.3	32.0	41.1	9.1
1.5	26.7	24.2	31.1	6.9
1.6	26.3	21.5	30.5	9.0
1.7	26.0	21.3	31.3	10.0
2.1	28.1	25.6	30.7	5.1
2.2	30.9	29.2	32.6	3.4
2.2	23.7	20.5	27.9	7.4

Table 12. Differences in L_{50} (mean, minimum, and maximum for nine earth cover types) for each hour of day, May-July, 1999-2003, Alaska.

Hour:	Mean	Min	Max	Diff.
0	28.6	21.5	37.7	16.3
1	28.7	21.5	37.6	16.1
2	29.2	21.3	37.0	15.7
3	29.2	21.3	36.9	15.6
4	29.1	22.6	36.9	14.3
5	28.5	22.6	36.2	13.6
6	28.2	20.9	35.7	14.8
7	28.2	21.0	33.7	12.7
8	27.9	20.8	34.1	13.3
9	28.0	20.5	36.4	15.9
10	28.2	22.2	37.0	14.8
11	28.7	23.2	38.2	15.0
12	29.5	23.0	38.1	15.1
13	30.2	25.5	38.9	13.5
14	31.3	27.3	40.4	13.2
15	30.8	24.6	39.7	15.1
16	31.2	27.9	41.1	13.2
17	30.5	25.5	40.5	15.0
18	30.2	26.1	39.2	13.1
19	29.5	25.3	37.3	12.0
20	29.0	24.2	37.0	12.8
21	28.8	23.5	36.0	12.5
22	28.8	23.2	36.8	13.6
23	28.5	22.2	37.3	15.1

Table 13. L_{90} dBA (median for all hours), YUKO 249.0 (2001 and 2003) and Bonanza Creek Experimental Forest (2001 and 2002), differences among years.

	YUKO 249.0			Bonanza Creek Exp. Forest		
Hour:	2001 (405 hrs.)	2003 (564 hrs.)	Diff.:	2001 (738 hrs.)	2002 (1512 hrs.)	Diff.:
0	25.9	23.9	2.0	18.7	20.1	1.4
1	25.6	24.0	1.6	18.5	19.8	1.3
2	25.6	24.3	1.3	18.5	20.0	1.5
3	25.3	23.8	1.5	18.2	20.7	2.5
4	23.5	24.1	0.6	18.3	20.2	1.9
5	24.7	23.9	0.8	18.2	20.2	2.0
6	23.6	22.8	0.8	19.2	20.8	1.6
7	25.0	22.7	2.3	19.2	21.8	2.6
8	25.0	23.1	1.9	19.5	21.9	2.4
9	25.0	23.9	1.1	20.5	22.0	1.5
10	25.2	24.1	1.1	20.4	23.1	2.7
11	25.4	24.7	0.7	21.5	23.3	1.8
12	25.6	25.4	0.2	21.7	24.5	2.8
13	26.7	24.7	2.0	21.6	24.5	2.9
14	26.6	25.0	1.6	21.6	24.3	2.7
15	26.8	24.1	2.7	22.3	24.1	1.8
16	26.5	23.9	2.6	21.3	23.4	2.1
17	27.0	24.1	2.9	22.5	23.7	1.2
18	27.8	24.7	3.1	21.1	23.2	2.1
19	26.0	24.9	1.1	20.4	23.6	3.2
20	25.8	24.3	1.5	19.9	22.1	2.2
21	25.1	24.0	1.1	20.0	20.6	0.6
22	26.0	23.4	2.6	19.2	19.8	0.6
23	25.3	23.7	1.6	19.7	19.7	0.0
		Mean:	1.6		Mean:	1.9
		Min.:	0.2		Min.:	0.0
		Max.:	3.1		Max.:	3.2
		Diff.:	2.9		Diff.:	3.2

Table 14. L₅₀ dBA (median for all hours), YUKO 249.0 (2001 and 2003) and Bonanza Creek Experimental Forest (2001 and 2002), differences among years.

	YUKO 249.0			Bonanza Creek Exp. Forest		
Hour:	2001 (405 hrs.)	2003 (564 hrs.)	Diff.:	2001 (738 hrs.)	2002 (1512 hrs.)	Diff.:
0	29.5	26.2	3.3	20.7	22.6	1.9
1	29.1	27.7	1.4	21.1	22.3	1.2
2	28.9	28.1	0.8	21.9	24.5	2.6
3	30.5	27.8	2.7	22.8	26.4	3.6
4	28.7	28.6	0.1	21.7	25.4	3.7
5	29.9	27.8	2.1	20.4	24.4	4.0
6	28.8	28.2	0.6	23.0	25.1	2.1
7	28.7	27.9	0.8	22.5	25.7	3.2
8	28.7	28.5	0.2	24.4	26.6	2.2
9	29.2	28.5	0.7	23.7	26.3	2.6
10	28.8	28.9	0.1	24.7	27.0	2.3
11	28.6	30.3	1.7	25.5	27.3	1.8
12	28.4	29.2	0.8	26.2	29.2	3.0
13	30.6	28.8	1.8	26.1	29.3	3.2
14	29.3	28.6	0.7	26.9	28.7	1.8
15	29.9	27.8	2.1	26.7	28.0	1.3
16	30.4	28.1	2.3	25.3	28.5	3.2
17	30.3	28.4	1.9	26.9	28.0	1.1
18	30.0	27.0	3.0	25.5	28.2	2.7
19	29.7	28.3	1.4	24.2	27.7	3.5
20	28.8	26.7	2.1	24.9	24.9	0.0
21	27.8	27.1	0.7	23.7	23.1	0.6
22	29.6	24.9	4.7	22.2	22.5	0.3
23	28.0	25.8	2.2	23.3	22.6	0.7
		Mean:	1.6		Mean:	2.2
		Min.:	0.1		Min.:	0.0
		Max.:	4.7		Max.:	4.0
		Diff.:	4.6		Diff.:	4.0

Discussion

Sound Levels: Natural ambient sound level

Natural ambient sound levels in most habitats in the YUKON MOAs were relatively low. Means for all hours and all habitats were between 20.0 dBA and 32.9 dBA. A recording studio has sound levels around 20 dBA; other examples of common sources of sounds and dBA levels are shown below.

	dBA
Threshold of human hearing	0
Inactive volcano crater	10
Recording studio	20
Insects (crickets, 5 m)	40
Conversational speech (1 m)	60
Snow machine (30 m)	80
Thunder	100
Military jet (30 m)	120

We presume that our measurements, made during summer months (May, June, and July), are among the loudest months with respect to natural sound sources. During winter months, there are fewer birds and insects, less vegetation (no leaves on trees), and no rain and thunder. Sounds from wind would still be present in winter, although sounds due to wind through vegetation would be less.

Natural ambient sound level data are needed when assessing potential impacts of proposed actions. When working with very large areas, such as the MOAs in Alaska or large national parks, models will be used to assess potential impacts. In most cases,

sound levels of proposed activities will be compared with natural ambient sound levels of the area under consideration, thus model accuracy will depend critically upon accurate baseline sound level data.

The most accurate metric to describe natural ambient sound levels is the median of all acoustic data, excluding non-natural sound sources. We believe the median is the most appropriate measure of central tendency for acoustic data because we have found that acoustic data are generally not normally distributed. This conclusion is based not only on the results of this study, but also on thousands of hours of data collected at several national parks. In nearly all cases, a few loud events in an otherwise generally quiet location result in a few data points at much higher levels than most data points (Ambrose and Florian 2002, Ambrose & Donaldson, unpublished data). As a result of this non-normal distribution, arithmetic averages tend to be skewed to higher levels. In these cases, the median is a better measure of central tendencies.

The most difficult aspect in calculating natural ambient sound levels is separating non-natural sound sources from natural sources in order to have data for which the median can be calculated. Currently, there is not an easy or automated method to separate non-natural from natural sources. For this reason, most regulations dealing with sound use an estimated value to describe the natural ambient sound level. The L_{90} is frequently used to estimate natural ambient sound levels (B & K 2002, Berglund and Lindvall 1995, Dunholter et al. 1989). In situations with relatively few non-natural sounds, such as <50 percent of the time, the L_{90} under-estimates the natural ambient sound level. For this

reason, the L_{50} metric is often advocated as an appropriate metric for estimating natural ambient sound levels. The L_{50} usually has similar but opposite problems as the L_{90} ; in situations where non-natural sounds occur, which is almost always the case, the L_{50} will over-estimate natural ambient sound levels. Thus, the most accurate estimate of the natural ambient sound level is generally something between the L_{50} and the L_{90} , depending on specific conditions which undoubtedly vary between locations. When non-natural sounds do occur, but the extent of those occurrences is unknown, the L_{90} is usually used to estimate natural ambient sound conditions.

For the habitats monitored in remote areas of Alaska, differences between mean L_{90} and L_{50} were generally within 3 dBA (mean difference 3.1 dBA; range 1.5-4.1 dBA). These small differences suggest that, while there could have been occasional loud, short-term sound events (as we know there were), these types of events were not numerous enough to substantially raise either metric. More attended source logging or long-term recordings would be needed to determine the exact number and sound levels of such events.

While the above discussion addresses efforts to estimate natural ambient sound levels for the primary habitats in the YUKON MOAs, decibel data alone do not and cannot completely describe acoustic conditions. Decibel data, with current technology, cannot provide information specific enough to identify the source of sounds. Knowledge of the source of sounds, and the duration, time, sound levels, and frequency content of those sounds are needed to fully describe and understand sound conditions. This study

collected decibel data and identified sources of sound >65 dBA, including sound levels and durations of those events. As technology improves and the ability to store more data easily, we recommend that identification and acoustic descriptions of all sources of sound, regardless of sound level, be collected in future studies.

Sound Levels: Routine Training and Cope Thunder Exercises

One of the mitigation measures in the final Record of Decision was to require a two week period between each major flying exercise, with only routine training to occur during that time. The intent of this measure was to provide periodic breaks between high impact periods when very large numbers of aircraft were flying in the MOAs, to lessen the overall impact on the soundscape. This study measured sound levels during major flying exercises and during the break periods when only routine training occurred. We were therefore able to better analyze extent to which the intent of this mitigation measure has been met.

Sound levels (L_{eq}) for periods with major flying exercises were generally higher than periods with routine training only (L_{eq} =69.3 dBA for major flying exercises; L_{eq} =64.2 for periods of routine training). At some locations in the YUKON MOAs, sound levels were higher during periods of routine training. This may be due to the random nature of training exercises, or it may be the measurement location was near a particularly good area or route frequently used for routine training activity and used less during major flying exercises.

The L_{eq} metric is used to compare differences between routine training and Cope Thunder exercises because this metric is greatly influenced by very loud events, even those of very short duration. An example of this is provided. At Birch Creek 2041, the location with the single loudest jet aircraft event, sound level metrics during routine training and during Cope Thunder exercises were:

	L_{eq}	L_{10}	L_{50}	L_{90}
Routine Training	39.5 dBA	38.7 dBA	35.8 dBA	34.6 dBA
Cope Thunder	62.6 dBA	42.2 dBA	38.3 dBA	35.4 dBA

From the greatly elevated L_{eq} , but relatively close L_{10} , L_{50} , and L_{90} , it is clear that there were some very loud but infrequent sound events. From the digital recordings of these loud events, we know the source of these sounds were jet aircraft. The L_{10} , L_{50} , and L_{90} metrics were reasonably close for both periods, suggesting the influence due to aircraft occurred less than 10 percent of the time. If very loud events occurred more than 10 percent of the time, the L_{10} would be greatly elevated.

Identification of Sources of Sounds >65 dBA

The most unique aspect of this study was, with the new equipment developed, the ability to save digital recordings of sound events that exceeded a user-defined threshold and duration, thus allowing us to identify the sources of those sounds. In previous acoustic

studies, inferences on source identification could be made via decibel data; however, one was never certain of the source of the sound. With digital recordings, we were able to identify sources of sound with 100 percent certainty. For all measurement locations in the YUKON MOAs, most sound events >65 dBA were due to jet aircraft.

Aircraft overflights in most areas of the YUKON MOAs are not common (especially in areas of the MOAs more distance from Eielson Air Force Base), but overflights that do occur are occasionally very loud, >100 dBA, even in areas with flight restrictions zones along the Yukon River. The maximum sound level recorded, 115.9 dBA, was from jet aircraft over Birch Creek in the YUKON 1 MOA (Figure 2). The maximum sound level in the restricted flight zone was 109.4 dBA at YUKO 249.0, a peregrine falcon nest site along the Yukon River.

Restricted flight zones were established as part of the Endangered Species Act Section 7 Consultation between the U. S. Air Force and the U. S. Fish and Wildlife Service. These zones consisted of no-fly areas anywhere below 2,000 feet Above Ground Level (AGL) within 2 miles horizontal distance from the Yukon, Charley, and Kandik rivers, areas of high density nesting peregrine falcons. The 2,000 foot AGL altitude was selected because observable effects in wildlife generally begin to appear at 85 dBA to 90 dBA, and startle or panic responses by most wildlife species occur at sound levels greater than 95 dBA (Eleventh Air Force 1992). Maximum, single event sound level (Max. dBA) at 2,000 feet slant distance for aircraft common in the MOAs are as follows (Aircraft Operations and Noise Data; Eleventh Air Force, 1995):

- F-16 87.4 dBA (84 percent RPM; 500 knots)
- F-15 89.2 dBA (85 percent RPM; 450 knots)
- A-10 <85 dBA (RPM not provided; 325 knots)

Thus, it was expected that sound levels would generally not exceed 85 dBA to 90 dBA within the restricted flight zones. A total of 19 jet aircraft sound events that exceeded 85 dBA (6 of these >90 dBA) were recorded at four of the six measurement locations along the Yukon and Charley rivers; the maximum sound level of these events was 109.4 dBA. The total number of jet aircraft events that exceeded 85 dBA within the restricted area is unknown. Assuming each sound level meter monitored (approximately) a one-mile radius around that location, all six sound level meters in the restricted flight area monitored approximately 18.8 square miles. The total restricted area along the Yukon and Charley rivers in the YUKON 1 and 2 MOAs is approximately 262 square miles (1 mile either side of 56 miles of the Yukon River and 75 miles of the Charley River). Thus, approximately 7 percent of the Yukon-Charley rivers area was monitored, and 19 events were recorded in this area. It follows that many more jet aircraft events >85 dBA likely occurred within this restricted area, but this number is unknown. With these decibel data on sound levels of jet aircraft events that occurred within the restricted flight area, and in consideration of maximum single event sound level data provided by the Air Force, it appears that either jet aircraft are using different (higher) power settings or flight speeds than reported in the EIS, or that jet aircraft are flying lower than 2,000 feet AGL within the restricted flight area. Thus, while the intent of the ROD mitigation measure to

limit or reduce very loud sounds from jet aircraft along the Yukon and Charley rivers are for the most part being met, there are occasions when jet aircraft sound levels exceed those in the ROD mitigation plan.

Sound levels (L_{90} and L_{50}) differences among habitats, hour of day, and years

An important aspect of this study was to describe baseline sound levels, the level against which future proposed activities can be modeled. As such, it is important to know if sound levels vary significantly among years for the same hour and same habitat. We collected acoustic data at nine different habitats or earth cover types during this study. At two locations, a substantial amount of data was collected two years. This provided us the opportunity to assess differences among hours, among habitats, and among years.

Several factors have the potential to influence sound levels, including different habitats (and associated animals), weather, hour of the day (and associated activities of animals at different times of the time and different weather patterns at different times of day), and seasonal differences. One would expect relatively little variation for the same hour at the same location over different years (unless a significant event such as a forest fire dramatically changed the habitat and thus changed animals present at the location).

The largest difference of L_{90} and L_{50} recorded during this study was among habitats, with a range of differences from ~12 to 16 dBA for both metrics. “Other Low Shrub” habitat was the quietest (Mean L_{90} =20.0 dBA for all hours and mean L_{50} =20.5 dBA for all

hours), while the “Closed Deciduous” habitat was the loudest (Mean L_{90} =32.1 dBA for all hours and Mean L_{50} =36.3 dBA for all hours). Weather influences (rain and wind) likely resulted in higher sound levels in the deciduous forest than in the low shrub habitat due to differences in foliage. Levels of animal activity, primarily song birds and associated vocalizations, may have been greater in the Closed Deciduous habitat than in Low Shrub habitat, and thus influenced sound levels.

Differences among hours of the day (in the same habitat) at lower latitudes are generally higher than these recorded in interior Alaska, and this may be due to the 24-hour daylight period during June and July in interior Alaska. In interior Alaska, the mean difference among hours (in the same habitat) for L_{90} was 4.8 dBA (range=3.0-8.5 dBA). At Zion National Park in southern Utah, mean difference among hours for L_{90} at one location was 23.3 dBA (range=22.0-45.3 dBA) and 13.8 dBA (range 20.0-33.8 dBA) at another (Ambrose and Florian 2002; Ambrose, unpublished data). Much of the difference at Zion National Park was due to increased insect activity, primarily crickets, during night hours. Such day and night differences are not common in interior Alaska.

The difference among years for the same hour at the same location was the smallest difference observed. For two locations with repeat measurements, the mean difference in the L_{90} was 1.6 dBA (range 0.2-3.1 dBA) for one location and 1.9 dBA (range 0.0-3.2 dBA) for the other. The mean difference in the L_{50} was 1.6 dBA (range 0.1-4.7 dBA) at one location and 2.2 dBA (range 0.0-4.0 dBA) at the other. A difference of 1.0 dBA is

detectible by a person with normal hearing, and a difference of 3.0 dBA is noticeable; hence, these differences among years were relatively small.

The relatively small mean differences among like hours in like habitats, and the relatively large mean differences among different habitats, support the concept of like habitats having similar acoustic conditions, and that those conditions remain similar over years. More data from like habitats for several years are needed to confirm this concept, but these limited data from interior Alaska appear to support the concept. Studies at Zion National Park, and most other areas, have been for short periods (<1 year); hence, multiple year data for the same location are not currently available.

Recommendations

This study measured acoustic conditions in major habitats in and near the YUKON MOAs, and recorded sources and sound levels of loud sound events. The study was limited to summer months when most resources could be impacted and when most flying exercises occurred. Acoustic studies are valuable from many perspectives, beyond monitoring sound levels relative to military aircraft. Acoustic studies have the potential to monitor several biological components of ecosystems, and future acoustic studies should expand to include these aspects whenever possible. Specific recommendations for future acoustic studies in the YUKON MOAs are listed below.

1. Establish a program to monitor changes in natural and non-natural sounds, with emphasis on monitoring areas within the 2-mile/2,000 feet AGL flight restricted areas to assess compliance with the Record of Decision mitigation plan;
2. Collect acoustic data during times of year not included in this study (winter);
3. When collecting additional acoustic data, include collection of long-term, high-quality digital recordings to provide a historical record of soundscapes being monitored;
4. For all future acoustic studies, use protocols being developed by NPS and FAA (Volpe Center) for acoustic measurements in national parks and fish and wildlife refuges;
5. Include more and longer-term high-quality digital recordings in future acoustic studies. Decibel data alone are not adequate to describe acoustic conditions, and must be supplemented with source identification, percent time different sources of sound are audible, and sound levels of the different sources; and
6. Integrate biological aspects into all acoustic monitoring programs, supplementing biological monitoring efforts whenever possible.

Acknowledgements

This study was one of several funded by the U. S. Air Force to assess potential impacts to resources in and near the YUKON MOAs due increases in permanent MOAs and increases in training activity. Mr. Jim Hostman, Environmental Engineer, 611th Air

Force, was instrumental in coordinating the various committees formed as a result of the Record of Decision, and as those committees selected the most appropriate studies, Mr. Hostman saw that the funding was allocated to the appropriate investigators. Without his efforts, it is unlikely that this effort would have succeeded as it has. Capt. Gary Roth, also 611th Air Force, provided leadership and assistance on the committees, and, as with Mr. Hostman, was instrumental in seeing these studies initiated. Both Mr. Hostman and Capt. Roth participated in our field work, and their assistance was greatly appreciated.

Chris Florian assisted with all phases of field work and data analysis, and was instrumental in keeping very large amounts of data organized and accessible. We appreciate her help.

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Appendix I. Glossary of Acoustic Terms

Acoustics

The science of sound.

Ambient Sound, Cumulative

All sounds associated with activities that generate similar sounds. When assessing potential impacts of sounds from a proposed action, the cumulative impacts of all activities with sound impacts similar to the proposed action must be considered.

Ambient Sound, Existing

All sounds associated with a given environment, including both natural and non-natural sounds. When considering potential impacts due to a specific sound source from a proposed action, it is understood that the existing ambient sound does not include the sounds of the proposed action.

Ambient Sound, Natural

All natural sounds associated with a given environment, including all sounds of nature and excluding all non-natural sounds. The natural ambient sound of a given environment is comprised of all natural sounds that occur in the absence of mechanical, electrical, and other non-natural sounds. Natural ambient sound is considered synonymous with the term “natural quiet,” although “natural ambient sound” is more appropriate because nature is not always quiet.

Ambient Sound, Source on Interest

All sounds associated with a specific sound source (aircraft, vehicle, boat, etc.).

Amplitude

The instantaneous magnitude of an oscillating quantity such as sound pressure. The peak amplitude is the maximum value.

Attenuation

The reduction of sound intensity by various means (e.g., air, humidity and porous materials).

Area of Audibility

The area within which a specific sound or sounds can be heard by a person with normal hearing.

Audibility

A measure of the biological properties of sound. Audibility is the ability of animals with normal hearing, including humans, to hear a given sound. Audibility is affected by the hearing ability of the animal, and by the frequency content and amplitude of the sound. In search of a more apt term, wherein several have been suggested (detectability, discernability, noticeability, etc.), none better has been found. Non-natural sound is often audible to wildlife and humans far from the sound source. The impact on natural sound is

represented by a “sound footprint” or a “soundprint,” the area where the sound level from the source is greater than the natural ambient sound level. The soundprint is an indicator of the area of direct impact of a sound source on the soundscape

Audiogram

A graph showing hearing acuity as a function of frequency.

Decibel

A logarithmic form of any measured physical quantity and commonly used in the measurement of sound. The decibel provides the possibility of representing a large span of signal levels in a simple manner as opposed to using the basic unit Pascal. The difference between the sound pressure for silence versus the sound pressure for a loud sound is a factor of 1,000,000:1 or more, and it is not practical to use these large numbers.

Doubling of Sound Pressure = 6 dB

Doubling of Sound Power = 3 dB

Doubling of Perceived Sound Level = 10 dB (approximately)

Doppler Effect (or Shift)

The apparent upward shift in frequency of a sound as a sound source approaches the listener or the apparent downward shift when the sound source recedes.

Energy Equivalent Sound Level (L_{eq})

The level of a constant sound over a specific time period that has the same sound energy as the actual (unsteady) sound over the same period. In park situations, L_{eq} is useful for quantifying intruding sounds because its magnitude depends heavily on the loudest periods of a time-varying sound. L_{eq} of an intruding source by itself, however, is inadequate for fully characterizing the intrusiveness of the source. Research has shown that judgments of the effects of intrusions in park environments depend not only upon the amplitude of the intrusion, but also upon the sound level of the “background,” in this case, the sound level of the non-intruding sources, usually the natural ambient sound levels. L_{eq} must be used carefully in quantifying natural ambient sound levels because occasional louder sound levels (gusts of wind, birds, insects) may heavily influence (increase) its value, even though the sound levels are typically not so loud.

Events per Hour

The number of times a non-natural source is heard, on average, in one hour (this may be specific to a particular non-natural sound or to all non-natural sounds). If this information is known, presentation and documentation provides another easily comprehended measure of how often the particular intruding sounds are heard. It provides an additional means for communicating the sense of the soundscape.

Frequency

The number of times per second that the sine wave of sound repeats itself. It can be expressed in cycles per second, or Hertz (Hz). Frequency equals Speed of Sound / Wavelength.

Hearing Range (human)

A healthy young person generally can hear frequencies from approximately 20 Hz to 20000 Hz, and sound pressure levels from 0 dB to 130 dB or more (threshold of pain). The smallest perceptible change is 1 dB.

Infrasound

Frequencies below 20 Hz. Humans perceive frequencies below about 20 Hz as pressure rather than sound.

Intensity

The sound energy flow through a unit area in a unit time.

Loudness

The subjective judgment of intensity of a sound by humans. Loudness depends upon the sound pressure and frequency of the stimulus. Loudness was defined by Fletcher and Munson (1933) as a physiological description of the magnitude of an auditory sensation. The definition of loudness was later refined as a definition of the attribute of auditory sensation corresponding most closely to the physical measurement of sound intensity, but is not always accurate. Loudness is a subjective quantity and all measurement techniques are based on assumptions and interpretation.

Masking

The process by which the threshold of audibility for a sound is raised by the presence of another (masking) sound. A masking sound is one that is intense enough to render inaudible or unintelligible another sound that is also present.

Noise

Traditionally, noise has been defined as unwanted, undesired, or unpleasant sound. This makes noise a subjective term. Sounds that may be unwanted and undesired by some may be wanted and desirable by others. Noise is sound (see definition of sound). In order to keep terms used in soundscape management as non-subjective as possible, sounds should be classified as either appropriate or inappropriate, rather than as “noise” or “sound.” The appropriateness of any sound in a given area will depend on a variety of factors, including the management objectives of that area.

Noise Free Interval

The length of the continuous period of time during which only appropriate sounds are audible. Though no research has been conducted to relate how this measure correlates with visitor judgments or with common experiences in park settings, it should provide a reasonable measure of the existence and availability of periods with only appropriate sounds. It is also a metric that requires no acoustics knowledge to be meaningful. Over the coming years of soundscape data collection, NPS will acquire such data and develop

an understanding of how this metric can best be used to aid in assessing and managing soundscapes.

Octave

The interval between two frequencies having a ratio of 2 to 1. For acoustic measurements, the octaves start at a 1000 Hz center frequency and go up or down from that point, at the 2:1 ratio. From 1000 Hz, the next filters' center frequency is 2000 Hz, the next is 4000 Hz, etc., or 500 Hz, 250 Hz, etc. Octave filtering is usually referred to as the class of octave filters typically 1, 3 or 12, thus creating full octaves, one-third octaves, or one-twelfth octaves.

Octave Band

The segment of the frequency spectrum separated by an octave.

Percent Exceedence (L_x)

These metrics are the sound levels (L), in decibels, exceeded x percent of the time. The L_{50} value represents the sound level exceeded 50 percent of the measurement period. L_{50} is the same as the median. The L_{90} value represents the sound level exceeded 90 percent of the time during the measurement period. For natural ambient environments, these levels generally differ by less than 3 to 5 dB because natural levels usually do not vary much over short periods of time (e.g., during an hour or two, unless there are highly variable conditions). L_{50} and L_{90} are useful measures of the natural sounds because in wildland situations, away from developed areas, they are less likely to be affected by non-natural sounds. Put another way, non-natural sounds in many wildland areas are likely to affect the measured sound levels for less than 50% of the time, and almost certainly for less than 90% of the time. L_{50} is used when there is high certainty that no non-natural sounds affect the measurements. L_{90} is used when non-natural occur during measurements.

Percent Time Above Natural Ambient

The amount of time that sound levels from non-natural sound(s) are greater than sound levels of natural ambient sound levels in a given area. This measure is not specific to the hearing ability of a given animal, but a measure of when and how long non-natural sound levels exceed natural ambient sound levels.

Percent Time Audible

The amount of time that various sound sources are audible to animals, including humans, with normal hearing (hearing ability varies among animals). A sound may be above natural ambient sound pressure levels, but still not audible to some animals. This information is essential for measuring and monitoring non-natural sound in wildland areas. These data can be collected by either a trained observer (attended logging) or by making high-quality digital recordings (for later playback). Percent Time Audible is useful because it is a measure that is understandable without any acoustics knowledge. It is a measure that can be specific to a given animal, and it is a metric that correlates well with visitor judgments of annoyance and with visitor reports of interference from certain sound sources with natural quiet and the sounds of nature.

Spectrum (Frequency Spectrum)

The amplitude of sound at various frequencies. It is given by a set of numbers that describe the amplitude at each frequency or band of frequencies.

Sound

A wave motion in air, water, or other media. It is the rapid oscillatory compressional changes in a medium that propagate to distant points. It is characterized by changes in density, pressure, motion, and temperature as well as other physical properties. Not all rapid changes in the medium are sound (wind distortion on a microphone diaphragm).

Soundscape

The total ambient acoustic environment associated with a given environment. It is also refers to the total ambient sound level for the area. Soundscapes are usually composed of both natural and non-natural sounds.

Sound Exposure Level (SEL)

The total sound energy of an actual sound during a specific time period. SEL is usually expressed using a time period of one second.

Sound Level

The *weighted* sound pressure level obtained by frequency weighting, generally A- or C-weighted. The weighting used must be clearly stated: For L_{Aeq} , “A” denotes that A-weighting was used, and “eq” indicates that an equivalent level has been calculated. Hence, L_{Aeq} is the A-weighted, energy-equivalent sound level.

Sound Level Floor

The lowest amplitude measurable by sound monitoring equipment. Most commercially available sound level meters and microphones can detect sound levels down to about 15 to 20 dBA; however, there are microphones capable of measuring sound levels below 0 dBA. This equipment is very expensive.

Sound Power (W)

The total sound energy radiated by a source per unit time. The unit of measurement is the Watt.

Sound Power Level (L_w)

The acoustic power radiated from a given sound source as related to a reference power level (typically 10^{-12} watts) and expressed as decibels. A sound power level of 1 watt = 120 dB (reference level = 10^{-12} watts).

Sound Pressure

Fluctuations in air pressure caused by the presence of sound waves. Sound pressure is the instantaneous difference between the actual pressure produced by a sound wave and the average barometric pressure at a given point in space. Not all pressure fluctuations

detected by a microphone are sound (e.g., wind over the microphone). Sound pressure is measured in Pascals (Pa), Newtons per square meter, which is the metric equivalent of pounds per square inch.

Sound Pressure Level (L_p or SPL)

The logarithmic form of sound pressure. In air, 20 times the logarithm (to the base 10) of the ratio of the actual sound pressure to a reference sound pressure (which is 20 micropascals, and by convention has been selected to be equal to the assumed threshold of human hearing). It is also expressed by attachment of the word decibel to the number.

Sound Speed

The speed of sound in air is about 344 m/sec (1,130 ft/sec or 770 mph) at 70° F at sea level.

Time Weighting

The response speed of the detector in a sound level meter. For Slow response, the response speed is 1 second. Slow time weighting is frequently used in environmental sound measurements. Fast response time is 1/8 second (0.125). This is less frequently used, but detects changes in sound levels more rapidly. Both Fast and Slow time weightings have been used in previous NPS acoustic studies, and, when compared over long measurement periods (over several days), there is very little difference in results (differences are often less than the accuracy of the meter). Fast and slow time weightings were developed, in part, to slow needle movement (called a “decay” factor) in analog meters so investigators could read and record sound levels. New digital sound level meters, while changing numbers rapidly on the screen, store data in memory for later analysis, thus, the ability to read numbers on the screen is less important. Hence, the most accurate “weighting” is none. Generally, 1-second Leq data are appropriate; however, when measuring sudden onset sound events such as sonic booms, more frequent data (many readings per second) may be appropriate.

Ultrasound

Sounds or a frequency higher than 20,000 Hz.

Wave

A particular type of disturbance that travels through a medium by virtue of the elastic properties of that medium.

Wavelength

Wavelength is the distance a wave travels in the time it takes to complete one cycle. A wavelength can be measured between successive peaks or between any two corresponding points on the cycle. $\text{Wavelength (ft)} = \text{Speed of Sound (ft)} / \text{Frequency (Hz)}$.

Windscreen

A porous device used to cover the microphone of a sound level measurement system. Windscreens are designed to minimize the effects of wind disturbance on the sound levels being measured.

These definitions were derived from several sources, including Acoustic Alliance (2001); American National Standards Institute (1976); Bruel & Kjaer (2002); Everest (2001); Hirschon (2002); Kelso and Perez (1983); and U. S. Environmental Protection Agency (1976).

Appendix II. Instrument and Setup Protocols

AC Output Weighting

For digital recordings using the AC output of the SLM, the AC output weighting shall be set to Flat, with appropriate gain setting for SLM or recording device in use

Attended Data Logging

Observers will conduct attended data logging approximately 50 m (150 feet) from the sound level meter, microphone, and/or tape recorder to ensure that field personnel can move about and conduct whispered conversations without influencing the measured sound. Observations during attended logging will be recorded on a standardized NPS data sheet.

Bird Spike

Spikes made of wire or hard plastic which prevents birds from perching on microphones and windscreens shall be used. Several companies sell bird spikes that fit on their microphones/windscreens.

Cables and Wiring

All cables and wiring shall be secured to prevent any sound which might be created in windy conditions (due to wiring hitting other objects). Good quality electric tape can be used to tape cables and wires.

Calibrator

A calibrator whose performance is essentially independent of off-reference atmospheric conditions (such as the B & K Model 4231) is recommended (Fleming et al. 1998). If an environmentally-sensitive sound calibrator is used, care must be taken to ensure that all measured sound level data are corrected in accordance with manufacturer's specifications.

Instrument Clocks

All clocks associated with the sound measurement effort shall be coordinated with GPS (Global Positioning System) time. This includes sound level meters, data loggers (notebook computer, Personal Digital Assistant-PDA), and all digital watches used during data logging. For long-term measurements, all clocks will be synchronized with GPS time at the beginning of the measurement period, and time differences with GPS time will be noted at the end of the measurement period. Acoustic data collected during the measurement period will be adjusted to correspond with GPS time.

Microphone type

A random incidence microphone is recommended (Fleming et al. 1998) for acoustic measurements in wildland settings. Microphones can be either polarized or pre-polarized.

Monitor Location

The microphone/pre-amplifier/windscreen shall be placed in a location representative of the habitat/acoustic zone under study. The microphone diaphragm should be placed 1.1 m to 1.5 m above the ground surface and oriented vertically (microphone grid facing the sky) (Fleming et al. 1998; ANSI 1992). For measurements related to vehicle sound, the microphone shall be placed 15 m (50 feet) from the centerline of the nearest traffic lane (ANSI 1992).

Solar Panels

All solar panels should be placed in a location with as little shading as possible and at least .3 m (12 inches) above the ground. Even the slightest shading will greatly diminish the panels output.

Sound Level Meter

Sound level meters shall be Type I or better and should perform true numeric integration and averaging in accordance with ANSI S1.4-1983.

Time Weighting

Sound level meters shall be set to Slow exponential time weighting, unless measuring sudden onset sound events such as sonic booms, in which case Fast weighting shall be used.

Windscreen

Windscreens which are effectively acoustically transparent (less than +/- 0.5 dB effect over the frequency span of interest) shall be used (ANSI 1992).

July 7, 2004 DRAFT

Appendix III. Photographs of equipment at various measurement locations.

PHOTOGRAPHS TO BE INSERTED IN FINAL.

Appendix IV. Tables XX-XX and Figures XX-XX. Acoustic metrics for all measurement locations in interior Alaska, 1999-2003.

DUE TO THE NUMBER AND SIZE OF TABLES AND FIGURES IN THIS APPENDIX, ONLY A SAMPLE OF THESE TABLES AND FIGURES ARE INCLUDED IN THIS DRAFT REPORT. THIS WAS DONE TO MINIMIZE THE SIZE OF THE REPORT IN ORDER TO FACILITATE ELECTRONIC TRANSMISSION TO REVIEWERS.

IF ANY REVIEWER WANTS TO SEE ALL OF THE TABLES AND FIGURES, WE WILL MAIL A CD OR HARD COPY.

Definitions and Explanations for Hourly Metrics Tables and Figures.

L_{eq} The level of a constant sound over a specific time period that has the same sound energy as the actual (unsteady) sound over the same period.

L_x The sound level (L), in decibels, exceeded *x* percent of the time. L₉₀ is one of the most important metrics because this metric is used estimate natural ambient sound conditions.

L_{max} The maximum sound level recorded.

L_{min} The minimum sound level recorded. In many wildland areas, sound levels can be less than some sound meters can measure. For this reason, the true lowest sound levels may not be known. In this study, it was clear from the data that sound levels were occasionally lower than our instruments could measure. This is apparent by looking at the tables and graphs; when the minimum sound level is often reported at the same level, like 18.5, for several hours, it is likely that the noise floor of the sound level meter, the lowest level that instrument can measure, is 18.5 dBA. In such cases, we can only state that sound levels were below 18.5 dBA. Because any L_{min} reported could be in error or misleading, the L_{min} was not plotted on graphs. The instruments used in this study, Larson-Davis Model 812 Sound Level Meter, generally could measure as low as 18 or 19 dBA.

Lines on Graphs

Lines on graphs between hourly metrics do not represent actual data; rather, the lines are intended to help lead the eye to the next like data point.

Table 1A. Birch Creek 2041, Alaska, Hourly Sound Levels (dBA), 6-09-2002 to 6-25-2002 (n=288).

Hour of Day	Number of Hours	Leq (Log Mean)	Leq (A. Mean)	Leq (Median)	L10 (Median)	L50 (Median)	L90 (Median)	LMin	LMax
0	12	43.3	43.0	43.3	44.8	42.5	40.8	34.1	74.0
1	12	42.7	42.4	42.7	43.7	42.2	40.1	36.0	49.6
2	12	43.0	42.6	42.5	43.9	42.5	40.4	36.0	53.5
3	12	43.1	42.5	41.5	43.4	41.5	39.6	33.6	50.2
4	12	42.4	41.8	42.0	43.6	41.7	39.9	34.5	51.3
5	12	42.7	42.2	42.1	44.3	41.5	39.7	34.4	53.1
6	12	42.3	41.8	42.2	44.0	41.9	39.5	33.6	54.0
7	12	41.6	40.6	40.5	42.9	40.2	36.9	31.7	65.0
8	12	40.0	38.6	37.7	39.5	35.9	35.0	31.9	76.1
9	11	41.4	39.6	38.3	39.3	35.9	34.7	30.9	73.2
10	11	45.1	42.7	43.2	44.8	38.0	35.1	30.7	68.2
11	12	70.1	44.1	41.1	43.5	37.9	35.2	32.4	114.7
12	12	40.4	39.7	39.3	40.5	36.7	35.2	30.8	68.3
13	12	54.9	42.3	40.5	42.2	36.9	35.2	32.2	91.8
14	12	42.5	39.5	38.0	39.3	36.0	34.8	30.5	70.4
15	12	45.0	41.0	40.2	40.1	36.5	34.4	30.3	76.3
16	13	42.3	40.1	37.1	39.1	35.9	34.3	29.8	70.5
17	13	50.6	44.0	41.5	42.7	36.3	34.8	30.5	84.9
18	12	41.3	40.1	40.9	41.5	37.3	35.5	31.6	76.5
19	12	40.5	39.5	39.3	41.3	37.9	36.3	30.8	60.5
20	12	40.1	39.5	39.5	42.2	37.8	35.5	31.1	66.5
21	12	41.9	40.7	39.8	42.3	38.6	36.2	32.5	69.0
22	12	42.0	41.3	41.4	43.5	40.1	37.9	32.2	64.0
23	12	43.2	42.8	42.9	44.5	42.1	40.0	33.9	77.6
								Min=29.8	Max= 114.7

Figure 1A. Birch Creek 2041, Alaska, Hourly Sound Levels (dBA), 6-09-2002 to 6-25-2002 (n=288).

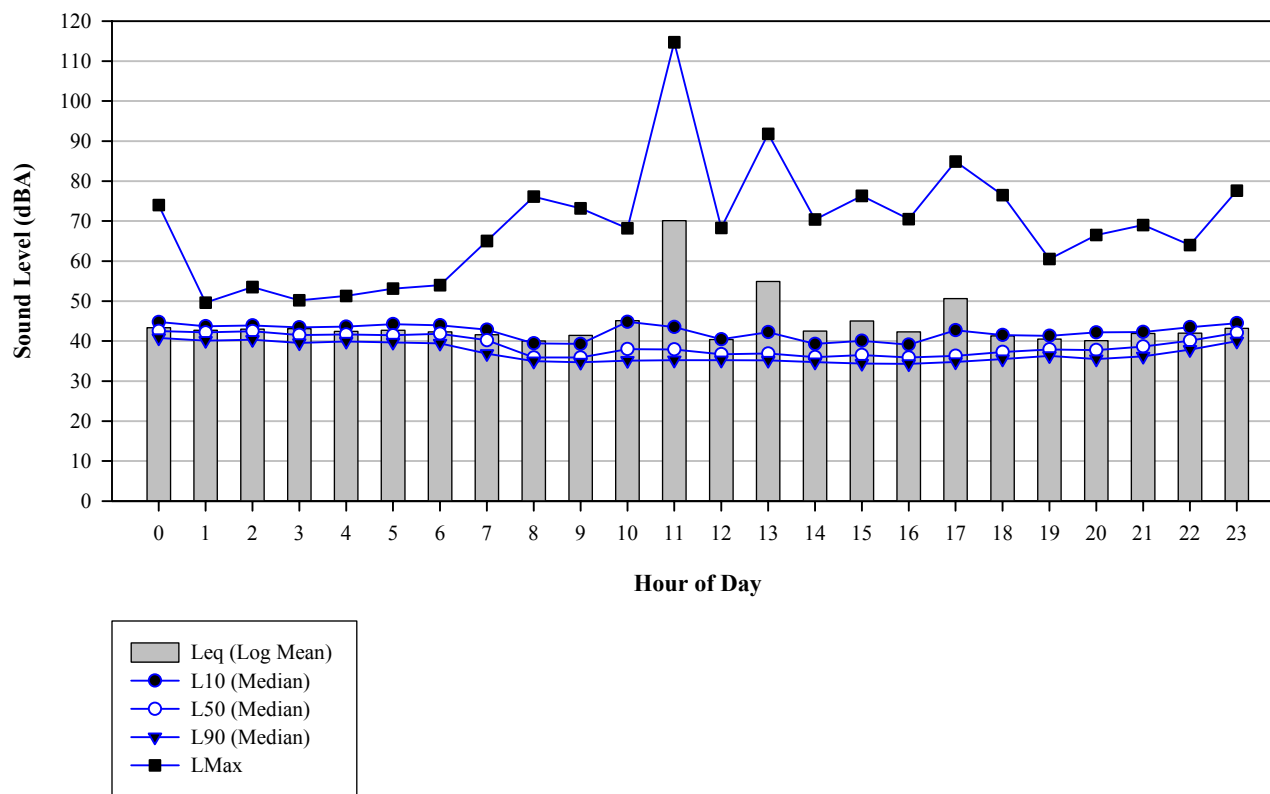


Table 2A. Birch Creek 2041, Alaska, Hourly Sound Levels (dBA), All Non-Cope Thunder Hours, 6-09-2002 and 6-22-2002 to 6-25-2002 (n=98).

Hour of Day	Number of Hours	Leq (Log Mean)	Leq (A. Mean)	Leq (Median)	L10 (Median)	L50 (Median)	L90 (Median)	LMin	LMax
0	4	43.8	43.3	43.3	45.0	42.1	38.9	34.1	74.0
1	4	41.9	41.7	41.8	43.4	41.3	39.3	36.0	49.6
2	4	42.2	41.7	40.9	42.4	40.4	38.8	36.7	53.5
3	4	42.0	41.5	41.3	43.4	40.6	39.3	35.9	50.2
4	4	41.3	42.2	41.8	43.4	41.3	38.9	34.5	49.4
5	4	41.6	42.1	41.5	43.4	41.0	39.1	34.4	53.1
6	4	40.7	40.4	40.0	42.0	39.3	37.4	33.6	54.0
7	4	39.5	38.9	39.0	40.6	38.7	35.5	31.7	51.1
8	4	36.6	36.5	36.1	37.2	35.7	34.7	32.2	55.5
9	4	42.0	39.8	39.8	41.3	35.7	35.0	31.4	64.1
10	4	36.8	36.4	36.0	36.7	35.4	34.7	31.7	55.9
11	4	40.4	39.9	40.3	40.3	36.8	34.9	33.5	66.3
12	4	40.5	40.0	40.2	40.7	36.0	34.9	30.8	68.3
13	4	39.4	39.0	38.9	41.8	37.0	35.0	32.6	63.3
14	4	37.6	37.4	37.5	38.7	36.0	34.6	32.0	65.8
15	4	38.9	38.2	38.9	39.1	35.8	34.1	31.1	72.6
16	5	39.6	37.7	36.9	38.5	35.6	34.0	29.8	63.2
17	5	42.2	38.1	35.1	36.6	34.2	33.5	30.5	79.7
18	4	37.7	36.9	36.1	38.6	34.4	33.5	31.6	62.9
19	4	38.3	38.0	37.8	40.8	36.6	34.2	30.8	55.7
20	4	38.7	38.4	39.4	42.0	36.1	34.3	31.1	55.3
21	4	40.6	40.1	39.8	42.4	38.4	35.6	32.5	55.7
22	4	42.2	41.4	41.1	43.6	39.7	37.9	34.2	59.0
23	4	43.0	43.0	42.9	45.1	42.5	40.0	33.9	53.9
		Leq (Log Mean)	Leq (A. Mean)	Leq (Median)	L10 (Median)	L50 (Median)	L90 (Median)	LMin	LMax
Flight Hours (1000-1800)		39.5	38.2	37.5	38.7	35.8	34.6	29.8	79.7

Figure 2A. Birch Creek 2041, Alaska, Hourly Sound Levels (dBA), All Non-Cope Thunder Hours, 6-09-2002 and 6-22-2002 to 6-25-2002 (n=98).

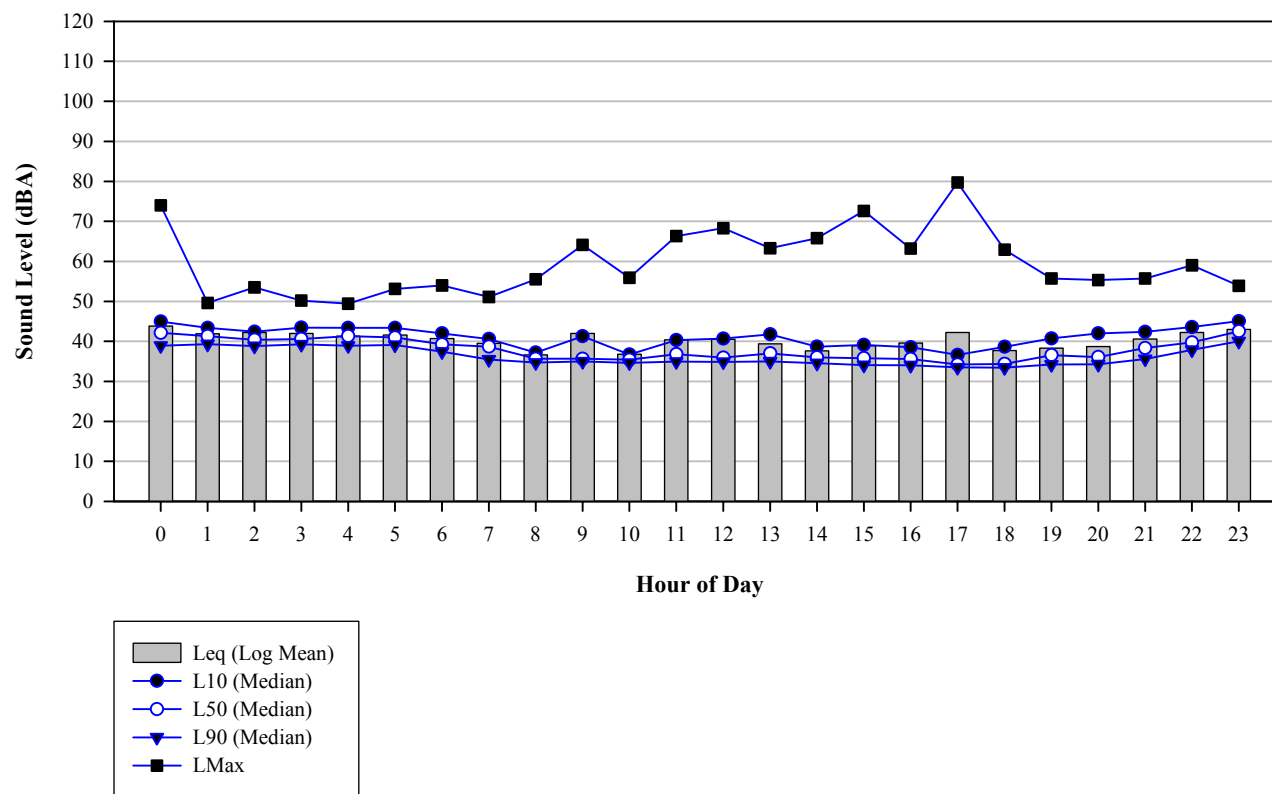


Table 3A. Birch Creek 2041, Alaska, Hourly Sound Levels (dBA), All Cope Thunder Hours, 6-10-2002 to 6-21-2002 (n=190).

Hour of Day	Number of Hours	Leq (Log Mean)	Leq (A. Mean)	Leq (Median)	L10 (Median)	L50 (Median)	L90 (Median)	LMin	LMax
0	8	43.0	42.8	43.3	44.8	42.9	41.0	36.4	53.0
1	8	43.0	42.7	42.7	43.7	42.6	41.5	36.2	49.3
2	8	43.4	43.1	42.9	44.2	42.9	40.9	36.0	50.2
3	8	43.6	43.0	42.7	44.0	42.5	40.8	33.6	50.0
4	8	42.9	42.5	42.4	44.0	42.3	40.5	35.7	51.3
5	8	43.2	42.8	42.7	44.6	42.4	40.8	35.9	49.3
6	8	43.0	42.5	42.7	44.2	42.5	40.8	34.6	53.2
7	8	42.3	41.4	40.6	43.0	40.2	38.1	31.9	65.0
8	8	41.0	39.7	38.8	40.9	37.5	35.6	31.9	76.1
9	7	41.0	39.6	38.3	39.3	36.2	34.4	30.9	73.2
10	7	46.8	46.2	46.3	48.4	39.3	36.5	30.7	68.2
11	8	71.9	46.2	41.5	44.7	38.3	35.5	32.4	114.7
12	8	40.3	39.5	39.3	39.9	37.0	35.3	32.0	65.5
13	8	56.6	44.0	41.5	42.2	36.9	35.2	32.2	91.8
14	8	43.8	40.5	38.0	39.4	36.0	34.8	30.5	70.4
15	8	46.4	42.3	40.5	41.4	38.6	35.4	30.3	76.3
16	8	43.4	41.5	42.1	42.2	39.7	35.5	31.2	70.5
17	8	52.5	47.6	49.3	48.9	38.3	34.9	32.3	84.9
18	8	42.4	41.6	42.2	42.5	39.9	36.3	32.0	76.5
19	8	41.2	40.3	40.6	41.7	39.9	37.6	31.8	60.5
20	8	40.6	40.0	41.3	42.4	40.8	37.2	32.7	66.5
21	8	42.4	41.0	40.4	42.1	38.6	36.7	33.8	69.0
22	8	41.9	41.3	41.4	43.5	40.6	38.2	32.2	64.0
23	8	43.4	42.8	42.7	43.9	41.4	40.0	34.6	77.6
		Leq (Log Mean)	Leq (A. Mean)	Leq (Median)	L10 (Median)	L50 (Median)	L90 (Median)	LMin	LMax
Flight Hours (1000-1800)		62.6	43.3	41.5	42.2	38.3	35.4	30.3	114.7

Figure 3A. Birch Creek 2041, Alaska, Hourly Sound Levels (dBA), All Cope Thunder Hours, 6-10-2002 to 6-21-2002 (n=190).

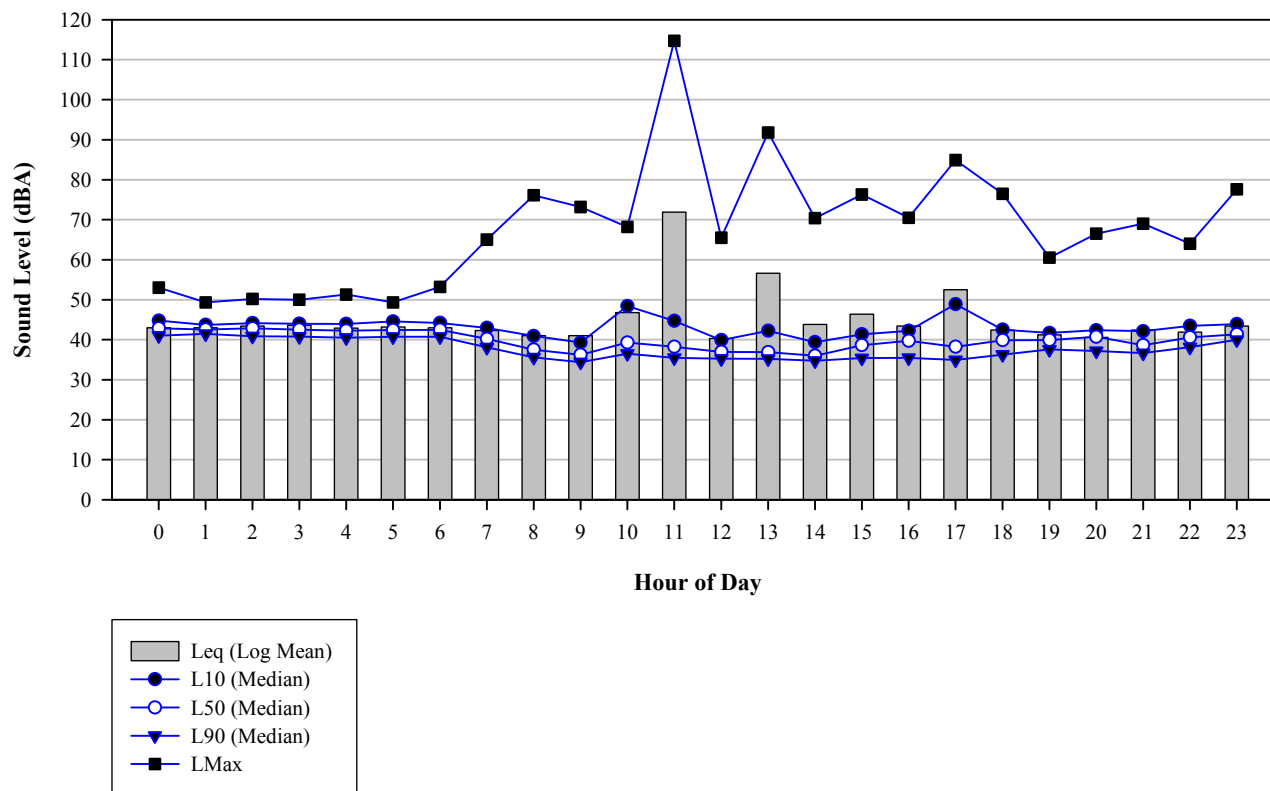


Table 4A. Yukon River 249.0 km, Alaska, Hourly Sound Levels (dBA), 6-08-2003 to 7-10-2003 (n=564).

Hour of Day	Number of Hours	Leq (Log Mean)	Leq (A. Mean)	Leq (Median)	L10 (Median)	L50 (Median)	L90 (Median)	LMin	LMax
0	24	39.4	34.1	33.5	35.1	26.2	23.9	19.2	62.8
1	24	39.0	36.4	36.1	38.2	27.7	24.0	19.5	72.5
2	24	40.2	37.5	38.7	40.2	28.1	24.3	19.0	67.2
3	24	42.4	38.1	39.9	40.0	27.8	23.8	18.3	68.0
4	24	42.4	40.8	42.3	43.6	28.6	24.1	17.9	80.2
5	24	42.3	41.2	41.1	43.1	27.8	23.9	18.0	71.6
6	24	42.3	41.0	40.2	42.9	28.2	22.8	17.7	73.1
7	23	42.4	41.3	40.8	42.5	27.9	22.7	17.9	74.7
8	23	42.7	41.2	41.4	42.6	28.5	23.1	17.8	66.8
9	22	43.2	41.5	41.4	42.4	28.5	23.9	18.6	75.3
10	23	44.5	41.0	41.9	41.5	28.9	24.1	19.0	74.0
11	22	42.4	41.0	40.6	42.0	30.3	24.7	18.7	71.2
12	23	42.5	41.2	41.2	43.4	29.2	25.4	19.3	70.7
13	24	40.7	39.6	39.7	41.1	28.8	24.7	19.1	70.4
14	23	40.9	39.2	39.1	40.9	28.6	25.0	19.0	75.4
15	23	42.9	39.1	38.2	39.8	27.8	24.1	18.9	74.3
16	23	41.4	38.0	37.6	39.2	28.1	23.9	18.2	64.8
17	23	45.2	40.6	40.1	42.0	28.4	24.1	19.0	79.6
18	24	44.4	40.8	40.0	41.8	27.0	24.7	19.1	88.6
19	24	41.7	39.0	38.6	40.2	28.3	24.9	19.0	74.9
20	24	39.2	37.5	36.9	37.6	26.7	24.3	18.9	64.5
21	24	39.9	38.9	39.5	37.8	27.1	24.0	19.2	63.2
22	24	37.7	33.8	31.9	31.9	24.9	23.4	18.9	65.6
23	24	38.8	31.8	30.5	30.2	25.8	23.7	18.7	65.4
								Min=17.7	Max= 88.6

**Figure 4A. Yukon River 249.0 km, Alaska, Hourly Sound Levels (dBA),
6-08-2003 to 7-10-2003 (n=564).**

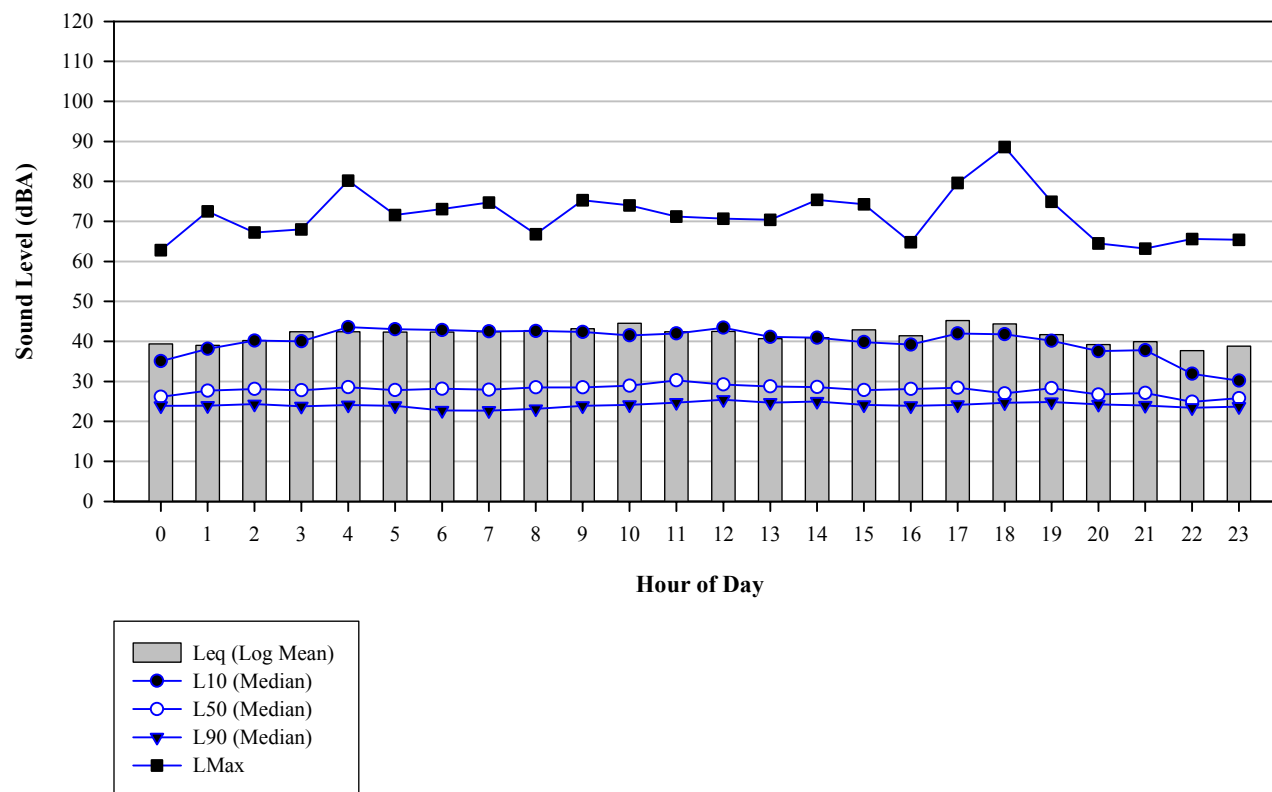


Table 5A. Yukon River 249.0 km, Alaska, Hourly Sound Levels (dBA), All Non-Cope Thunder Hours, 6-08-2003 to 6-09-2003 and 6-25-2003 to 7-10-2003 (n=385).

Hour of Day	Number of Hours	Leq (Log Mean)	Leq (A. Mean)	Leq (Median)	L10 (Median)	L50 (Median)	L90 (Median)	LMin	LMax
0	16	40.7	34.1	32.6	32.9	25.7	23.3	19.2	62.8
1	16	39.7	36.2	35.9	38.2	27.7	23.9	19.5	72.5
2	16	39.6	35.9	34.0	37.4	27.1	24.5	19.0	67.2
3	16	40.5	35.0	35.2	37.3	26.3	23.7	18.3	68.0
4	16	41.9	39.7	41.1	42.3	27.5	23.9	17.9	80.2
5	16	42.1	41.2	40.7	43.1	27.4	23.9	18.0	71.6
6	16	42.5	41.3	40.0	42.9	28.2	22.3	17.7	73.1
7	15	42.2	40.9	40.2	42.4	27.0	22.2	17.9	74.7
8	15	42.8	40.7	40.7	41.7	26.9	22.8	17.8	66.8
9	14	43.9	41.9	41.3	42.4	28.0	23.4	18.6	75.3
10	15	41.2	39.7	38.6	38.8	28.0	23.8	19.0	65.8
11	15	42.1	40.4	40.5	40.6	29.0	24.3	18.7	71.2
12	16	43.0	41.6	41.7	43.9	29.0	24.2	19.3	70.3
13	17	41.1	39.7	39.9	41.2	28.7	24.6	19.1	70.4
14	16	41.3	39.4	38.9	40.2	28.1	24.5	19.0	75.4
15	16	43.8	39.0	38.2	38.4	27.3	24.1	18.9	74.3
16	16	42.3	37.9	37.1	38.5	26.0	23.5	18.2	64.8
17	16	46.0	40.3	40.0	40.6	27.2	23.6	19.0	79.6
18	17	45.3	41.2	40.5	42.0	26.1	23.8	19.1	88.6
19	17	42.5	39.6	39.1	40.0	26.0	23.8	19.0	74.9
20	17	39.2	37.2	36.7	35.4	25.7	22.9	18.9	64.5
21	17	40.0	39.0	39.0	37.9	24.5	22.6	19.2	62.3
22	17	38.7	34.9	34.3	32.2	23.9	22.2	18.9	65.6
23	17	40.2	32.9	31.4	29.7	25.3	23.3	18.7	65.4
		Leq (Log Mean)	Leq (A. Mean)	Leq (Median)	L10 (Median)	L50 (Median)	L90 (Median)	LMin	LMax

Flight Hours (1000-1800)	43.3	39.9	39.9	40.6	28.0	24.1	18.2	88.6
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Figure 5A. Yukon River 249.0 km, Alaska, Hourly Sound Levels (dBA), All Non-Cope Thunder Hours, 6-08-2003 to 6-09-2003 and 6-25-2003 to 7-10-2003 (n=385).

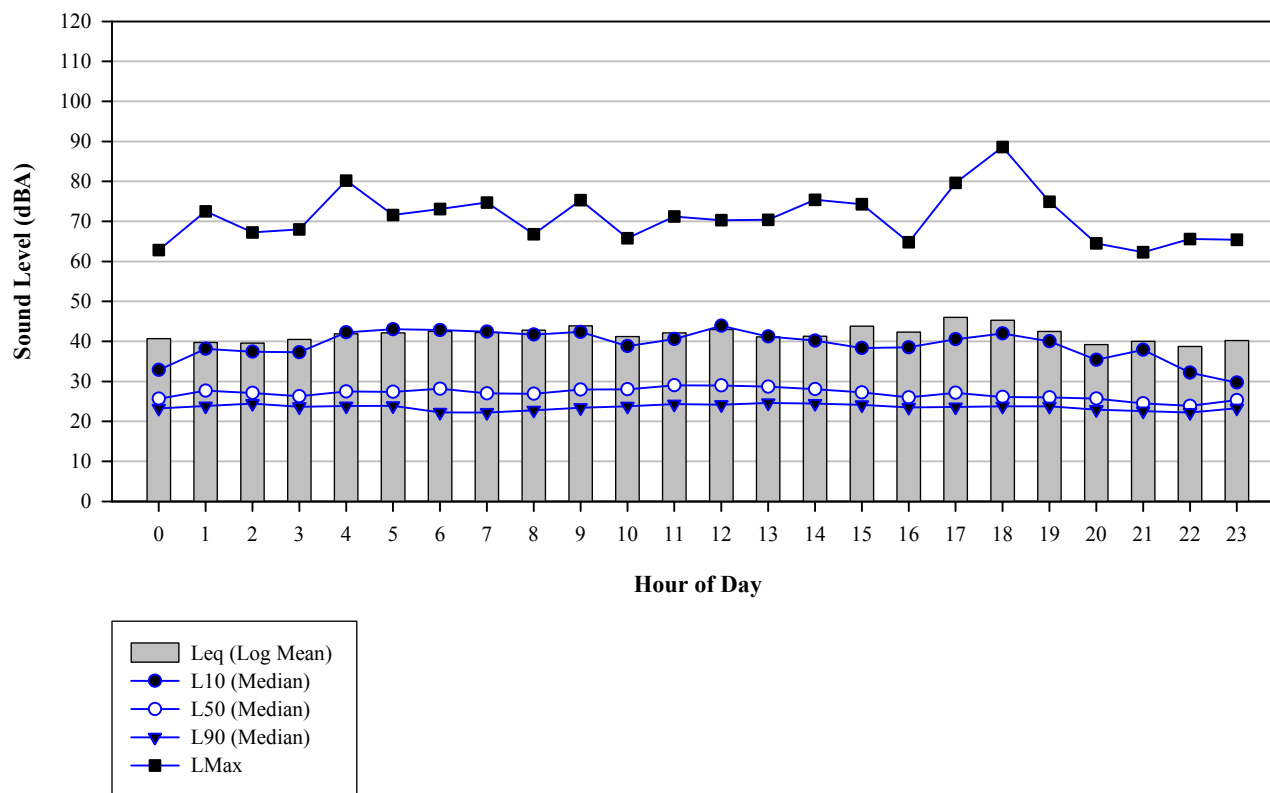


Table 6A. Yukon River 249.0 km, Alaska, Hourly Sound Levels (dBA), All Cope Thunder Hours, 6-10-2003 to 6-17-2003 (n=179).

Hour of Day	Number of Hours	Leq (Log Mean)	Leq (A. Mean)	Leq (Median)	L10 (Median)	L50 (Median)	L90 (Median)	LMin	LMax
0	8	34.7	34.2	33.7	36.8	27.5	24.7	21.3	61.0
1	8	37.3	36.7	36.5	38.9	27.7	24.2	21.3	63.8
2	8	41.1	40.7	40.3	41.9	28.7	24.2	21.4	64.2
3	8	44.8	44.3	45.1	45.7	31.0	25.0	21.3	66.3
4	8	43.3	42.9	42.9	43.8	30.6	24.4	20.6	68.4
5	8	42.6	41.3	41.7	43.1	28.5	23.6	20.7	65.0
6	8	41.9	40.5	41.4	42.6	28.5	24.8	20.4	65.4
7	8	42.8	42.1	42.7	42.7	29.3	25.7	20.6	65.2
8	8	42.5	42.1	41.6	43.2	32.7	25.9	20.9	65.8
9	8	41.8	40.9	41.6	43.0	31.5	24.9	21.0	63.5
10	8	47.6	43.6	43.7	45.2	33.0	25.2	21.1	74.0
11	7	43.0	42.3	42.7	43.0	33.1	28.4	21.9	67.7
12	7	40.9	40.3	41.0	41.8	34.6	31.0	21.7	70.7
13	7	39.6	39.2	38.6	40.7	34.8	30.3	22.3	61.6
14	7	39.7	38.9	39.3	40.9	32.3	28.1	21.7	64.4
15	7	39.7	39.1	40.4	42.6	31.4	27.7	21.4	61.4
16	7	38.5	38.2	38.0	40.6	33.5	29.2	21.7	58.3
17	7	42.1	41.2	40.9	42.4	32.9	26.9	21.8	70.4
18	7	40.6	39.9	39.5	41.6	33.0	29.8	22.2	61.8
19	7	38.8	37.7	37.3	40.3	32.0	28.0	22.5	64.2
20	7	39.3	38.0	38.6	40.5	30.9	27.0	22.7	62.3
21	7	39.6	38.9	39.5	37.7	33.0	28.5	22.6	63.2
22	7	33.9	31.1	29.6	29.5	27.0	25.7	22.3	63.4
23	7	29.7	28.9	28.8	30.2	26.2	24.3	21.0	54.1
		Leq (Log Mean)	Leq (A. Mean)	Leq (Median)	L10 (Median)	L50 (Median)	L90 (Median)	LMin	LMax

Flight Hours (1000-1800)	42.3	40.3	40.4	41.8	33.0	28.4	21.1	74.0
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Figure 6A. Yukon River 249.0 km, Alaska, Hourly Sound Levels (dBA), All Cope Thunder Hours, 6-10-2003 to 6-17-2003 (n=179).

